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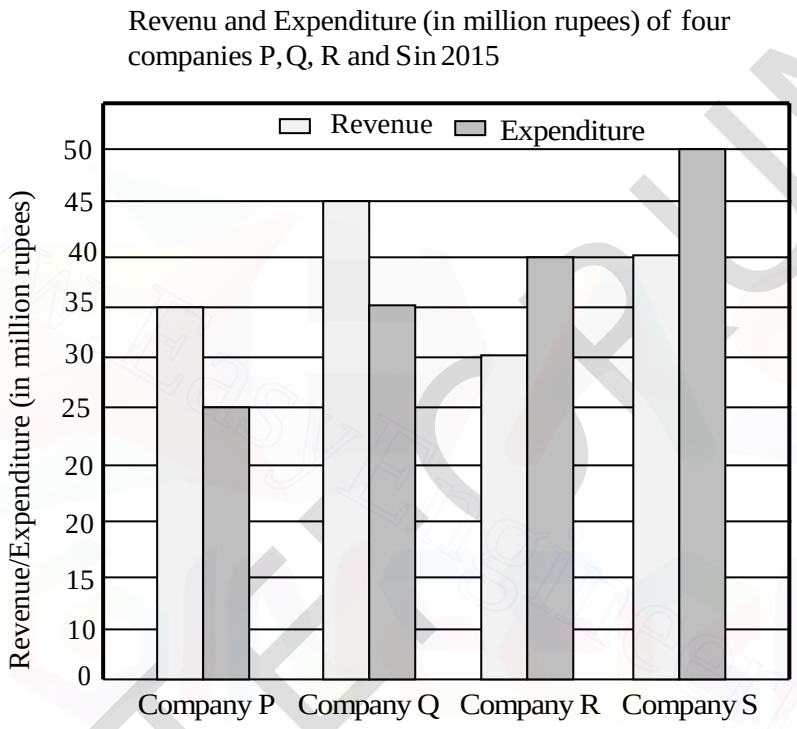
GENERAL APTITUDE

1. The revenue and expenditure of four different companies P, Q, R and S in 2015 are shown in the figure. If the revenue of company Q in 2015 was 20% more than that in 2014, and company Q had earned a profit of 10% on expenditure in 2014, then its expenditure (in million rupees) in 2014 was _____.



(A) 32.7 (B) 35.1 (C) 34.1 (D) 33.7

Key: (C)

Sol: From the given chart;

Revenue of company Q in 2015 = 45 million

Let us assume that revenue of company Q in 2014 = x million

$$\therefore x \times \frac{120}{100} = 45 \Rightarrow x = 37.5 \text{ million}$$

[Q revenue of Q in 2015 was 20% more than that in 2014]

Let us assume that,

Expenditure of company Q in 2014 = y million

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$$\therefore \text{Profit \%} = \frac{\text{income} - \text{expenditure}}{\text{expenditure}} \times 100$$

$$\Rightarrow 10 = \frac{37.5 - y}{y} \times 100 \,(\text{Q income} \to \text{revenue})$$

$$\Rightarrow \frac{y}{10} + y = 37.5 \Rightarrow \frac{11y}{10} = 37.5 \Rightarrow y = 34.1 \text{ million}$$

2. Select the word that fits analogy:

Do: Undo: Trust:

(A) Distrust (B) Untrust (C) Entrust (D) Intrust

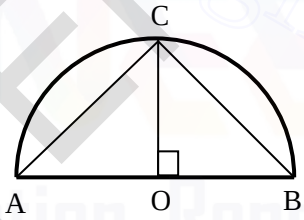
Key: (A)

3. Stock markets _____ at the news of the coup.

(A) probed (B) poised (C) plunged (D) plugged

Key: (C)

4. Given a semicircle with O as the centre, as shown in the figure, the ratio $\frac{\overline{AC} + \overline{CB}}{\overline{AB}}$ is where $\overline{AC}, \overline{CB}$ and $\overline{AB}$ are chords.



(A) $\sqrt{2}$ (B) $\sqrt{3}$ (C) 2 (D) 3

Key: (A)

Sol: From the figure, we have

$OA = OB = OC$

Using Pythagoras theorem, in Δ^{le} OAC; $AC^2 = OA^2 + OC^2$

$= 2(OA^2)[\text{Q } OC = OA]$

$\overline{AC} = \sqrt{2}\, OA \quad ...(1)$

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In $\Delta^{le}OBC$, $CB^2 = OC^2 + OB^2$

$= 2OC^2$ [Q $OC = OB$]

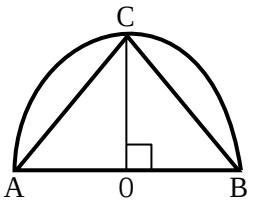
$\Rightarrow \overline{CB} = \sqrt{2}\ OC \ldots(2)$

$\therefore \dfrac{\overline{AC} + \overline{CB}}{\overline{AB}} = \dfrac{\sqrt{2}OA + \sqrt{2}OC}{\overline{AB}}$

$= \dfrac{\sqrt{2}\ \overline{OA} + \sqrt{2}\ \overline{OA}}{2\overline{OA}}$ [Q $\overline{OC} = \overline{OA}$ & $\overline{AB} = \overline{AO} + \overline{OB} = 2\overline{OA}$]

$= \dfrac{2\sqrt{2}}{2} = \sqrt{2}$

$\Rightarrow \dfrac{\overline{AC} + \overline{CB}}{\overline{AB}} = \sqrt{2}$



5. If P, Q, R, S are four individuals, how many teams of size exceeding one can be formed, with Q as a member?

(A) 5 (B) 8 (C) 6 (D) 7

Key: (D)

Sol: P, Q, R, S → are four individuals

Teams of size exceeding one:

size of 2	size of 3	size of 4
PQ	PRQ	PRSQ
RQ	PSQ	
SQ	RSQ	

∴ Total number of teams possible = 7

6. Select the next element of the series: Z, WV, RQP, _____

(A) LKJI (B) NMLK (C) KJIH (D) JIHG

Key: (C)

7. People were prohibited _____their vehicles near the entrance of the main administrative building.

(A) to have parked (B) to park

(C) from parking (D) parking

Key: (C)

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8. Non-performing Assets (NPAs) of a bank in India is defined as an asset, which remains unpaid by a borrower for a certain period of time in terms of interest, principal, or both. Reserve bank of India (RBI) has changed the definition of NPA thrice during 1993-2004, in terms of the holding period of loans The holding period was reduced by one quarter each time. In 1993, the holding period was four quarters (360 days).

Based on the above paragraph, the holding period of loans in 2004 after the third revision was _____ days.

(A) 45 (B) 135 (C) 180 (D) 90

Key: (D)

9. This book, including all its chapters, _____ interesting. The students as well as the instructor _____ in agreement about it.

(A) is, are (B) are, are (C) is, was (D) were, was

Key: (A)

10. In four-digit integer numbers from 1001 to 9999, the digit group "37" (in the same sequence) appears _____ times.

(A) 299 (B) 270 (C) 279 (D) 280

Key: (D)

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ELECTRICAL ENGINEERING

Q. No. 1 to 25 Carry One Mark Each

1. The value of the following complex integral, with C representing the unit circle centered at origin in the counterclockwise sense, is:

$$\int_C \frac{z^2+1}{z^2-2z}dz$$

(A) πi (B) $-8\pi i$ (C) $-\pi i$ (D) $8\pi i$

Key: (C)

Sol: Given, $I=\int_C \frac{z^2+1}{z^2-2z}dz$

Where C is unit circle as origin in the counter clockwise direction.

We know, by Cauchy's integral formula.

If f(z) is analytic within and on a closed curve and if a is any point with in C, then

$$f(a)=\frac{1}{2\pi i}\int_C \frac{f(z)dz}{(z-a)}$$

Here, pole z = 0 lies within $|z|=1$

So, we can apply integral theorem to it and z = 2 lies outside $|z|=1$

$$\therefore \quad I=\int_C \frac{\left[(z^2+1)/(z-2)\right]}{z}dz$$

$$=\int_C \frac{f(z)}{z}dz \qquad \text{where } f(z)=\frac{(z^2+1)}{(z-2)}$$

$$=2\pi i f(0) \qquad \{\text{using Integral theorem}\}$$

$$=2\pi i\left(\frac{z^2+1}{z-2}\right)\Big|_{z=0}$$

$$=2\pi i\times\frac{-1}{2}$$

$$=-\pi i$$

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2. Consider a negative unity feedback system with forward path transfer function $G(s)=\frac{K}{(s+a)(s-b)(s+c)}$, where K, a, b, c are positive real numbers. For a Nyquist path enclosing the entire imaginary axis and right half of the s-plane in the clockwise direction, the Nyquist plot of $(1+G(s))$, encircles the origin of $(1+G(s))$-plane once in the clockwise direction and never passes through this origin for a certain value of K. Then, the number of poles of $\frac{G(s)}{1+G(s)}$ lying in the open right half of the s-plane is _____.

Key: (2)

Sol: Given, Forward transfer function $G(s)=\frac{K}{(s+a)(s-b)(s+c)}$; $K,a,b,c>0$

$1+G(s)$ encircles origin once in clockwise direction we have to find number of poles of $\frac{G(s)}{1+G(s)}$

i.e., closed loop transfer function in the right half of s-plane.

We know,

If 1 + G(s) encircles origin, then G(s) encircles (–1, 0)

For encirclement of G(s) about (–1, 0)

We have

N = P – Z where

N = Number of encirclements

+ for ACW direction

- for CW direction

P = Number of open loop poles in the right half of s-plane

Z = Number of closed loop poles in the right half of s-plane

Here, N = –1, P = 1, Z =?

Then, $-1 = 1 - Z \Rightarrow Z = 2$

Hence, the correct answer is (2).

3. Out of the following options, the most relevant information needed to specify the real power (P) at the PV buses in a load flow analysis is

(A) rated voltage of the generator

(B) rated power output of the generator

(C) solution of economic load dispatch

(D) base power of the generator

Key: (B)

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Sol: In a PV bus, the real power and voltage are specified for buses that are generators. Hence the quantity 'P' at this bus is the rated power output of generator.

4. A single 50 Hz synchronous generator on droop control was delivering 100 MW power to a system. Due to increase in load, generator power had to be increased by 10MW, as a result of which, system frequency dropped to 49.75 Hz. Further increase in load in the system resulted in frequency of 49.25 Hz. At this condition, the power in MW supplied by the generator is _____ (rounded off to 2 decimal places).

Key: (130)

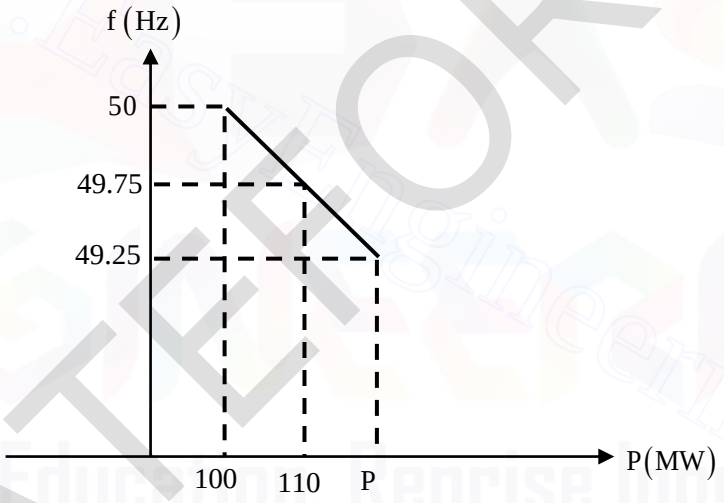
Sol: At 50 Hz, generator delivering 100MW.

When generator load increases by 10MW, f = 49.75Hz

When generator load further increases and becomes f = 49.25 Hz

We have to find the power supplied by generator when frequency drops to 49.25 Hz i.e. P

The given data is represented as shown below



As the slope of $\frac{\Delta f}{\Delta P}$ = constant; we have

$$\frac{50-49.75}{100-110}=\frac{49.75-49.25}{110-P}$$

$$\Rightarrow \frac{0.25}{-10}=\frac{0.50}{110-P}$$

$$\Rightarrow 110-P=-20$$

$$\Rightarrow P=110+20=130\text{MW}$$

Hence, the correct answer is 130MW

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5. x_R and x_A are, respectively, the rms and average values of $x(t)=x(t-T)$, and similarly, y_R and y_A are, respectively, the rms and average values of $y(t)=kx(t)$. k,Tare independent of t. Which of the following in true?

(A) $y_A \neq kx_A; y_R = kx_R$

(B) $y_A \neq kx_A; y_R \neq kx_R$

(C) $y_A = kx_A; y_R = kx_R$

(D) $y_A = kx_A; y_R \neq kx_R$

Key: (C)

Sol: Given, RMS of $x(t)=x(t-T)=X_R$

Average of $x(t)=x(t-T)=X_A$

RMS of $y(t)=kx(t)=Y_R$

Average of $y(t)=kx(t)=Y_A$

We have to select the correct relation between X_R and Y_R and X_A and Y_A

We know,

- RMS of $x(t)=X_R=\sqrt{\frac{1}{T}\int_0^T x^2(t)dt}$
- Average of $x(t)=X_A=\frac{1}{T}\int_0^T x(t)dt$

Then, $Y_R=\sqrt{\frac{1}{T}\int_0^T y^2(t)dt}=\sqrt{\frac{1}{T}\int_0^T k^2x^2(t)dt}$

$=k\sqrt{\frac{1}{T}\int_0^T x^2(t)dt}$

$=k.X_R$

$\Rightarrow Y_R=kX_R$

$Y_A=\frac{1}{T}\int_0^T y(t)dt=\frac{1}{T}\int_0^T k.x(t)dt=\frac{k}{T}\int_0^T x(t)dt=k.X_A$

$\Rightarrow Y_A=k.X_A$

6. A single-phase inverter is fed from a 100V dc source and is controlled using a quasi-square wave modulation scheme to produce an output waveform, v(t), as shown. The angle σ is adjusted to entirely eliminate the 3rd harmonic component from the output voltage. Under this condition, for v(t), the magnitude of the 5th harmonic component as a percentage of the magnitude of the fundamental component is _____ (rounded off to 2 decimal places).

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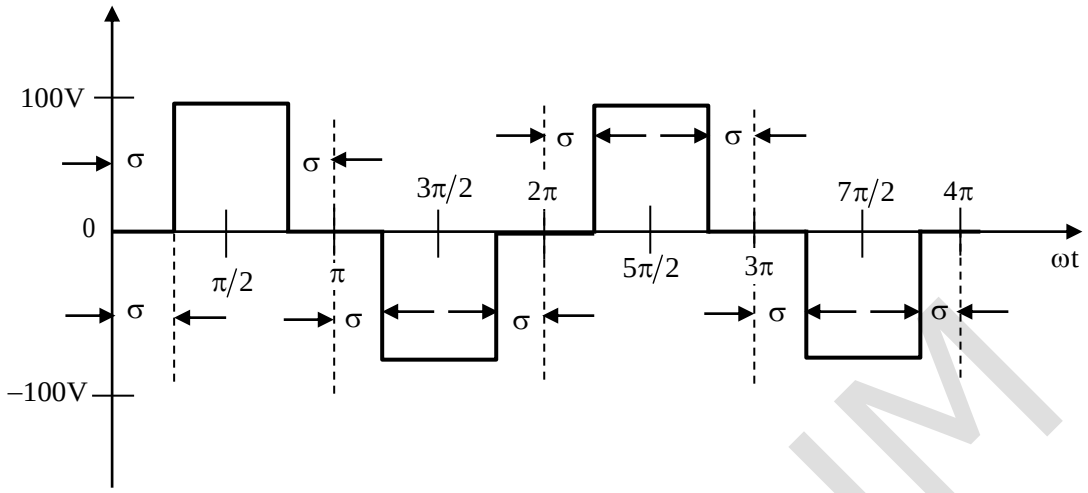

Key: **(20)**

Sol: Given, a single-phase inverter

We have to find the magnitude of 5th harmonic component as a percentage of the magnitude of the fundamental component when third harmonic component is zero in the output.

We know,

From single pulse width modulation scheme, output voltage is given by

$$V_o(t) = \sum_{n=1,3,5...}^{\infty} \frac{4V_s}{n\pi} \sin nd \sin \frac{n\pi}{2} \sin n\omega t$$

To eliminate n^{th} harmonic, we must have $\sin nd = 0$

For 3rd harmonic, $d = \frac{180}{3} = 60°$

Then, $$\frac{V_{05}}{V_{01}} = \frac{\frac{4V_s}{5\pi}\sin(5\times 60°)\sin\frac{5\pi}{2}}{\frac{4V_s}{\pi}\sin(60°)\sin\frac{\pi}{2}} = -\frac{1}{5}$$

Or, $$\left|\frac{V_{05}}{V_{01}}\right| \times 100 = 0.2 \times 100 = 20\%$$

Hence, the correct answer is 20%.

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7. Consider the initial value problem below. The value of y at $x = \ln 2$, (rounded off to 3 decimal places) is _____.

$$\frac{dy}{dx} = 2x - y, \quad y(0) = 1$$

Key: **(0.863)**

Sol: Given, $\frac{dy}{dx} = 2x - y$ and $y(0) = 1$ then $y(\ln 2)$ we need to calculate

$$\frac{dy}{dx} + y = 2x$$

$$I.f = e^{\int p dx} + e^{\int dx} = e^x$$

$$\Rightarrow e^x y = \int e^x 2x + c$$

$$\Rightarrow e^x y = 2xe^x - 2e^x + c$$

$$y = 2x - 2 + \frac{c}{e^x} \Big| \; Q\; y(0) = 1$$

$$1 = 0 - 2 + c \Rightarrow c = 3$$

$$\therefore y = 2x - 2 + \frac{3}{e^x}$$

Hence at $x = \ln 2$, $y = 2\ln 2 - 2 + \frac{3}{e^{\ln 2}}$

$$y = 1.3862 - 2 + \frac{3}{2}$$

$$y = 0.8863$$

Hence $y(\ln 2) = 0.8863$

8. A three-phase, 50Hz, 4-pole induction motor runs at no-load with a slip of 1%. With full load, the slip increases to 5%. The % speed regulation of the motor (rounded off to 2 decimal places) is _____.

Key: **(4.21)**

Sol: Given, f = 50Hz, P = 4

No load slip, $S_{NL} = 1\%$

Full load slip, $S_{FL} = 5\%$

We have to find % speed regulation of the induction motor

We know,

$$\% \text{ speed regulation } = \frac{N_{N_L} - N_{FL}}{N_{FL}} \times 100$$

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Speed of motor, $N_r = (1-s)N_s$,

$N_s \rightarrow$ Synchronous speed

$$N_s = \frac{120f}{P} = \frac{120\times 50}{4} = 1500 \text{ rpm}$$

$$N_{NL} = (1-s_{NL})1500 = (1-0.01)\times 1500 = 1485 \text{ rpm}$$

$$N_{FL} = (1-s_{FL})1500 = (1-0.05)\times 1500 = 1425 \text{ rpm}$$

$$\therefore \%\text{ speed regulation } = \frac{1485-1425}{1425}\times 100 = 4.21\%$$

Hence the correct answer is 4.21.

9. A common-source amplifier with a drain resistance, $R_D = 4.7k\Omega$ is powered, using a 10V power supply. Assuming that the transconductance, g_m, is $520\,\mu A/V$, the voltage gain of the amplifier is closest to:

(A) –2.44 (B) –1.22 (C) 2.44 (D) 1.22

Key: (A)

Sol: Given, a common source amplifier with drain resistance, $R_D = 4.7\text{ k}\Omega$

Transconductance, $g_m = 520\,\mu A/V$

Power supply = 10V

We have to find voltage gain of the amplifier

we know, from the AC model of common source amplifier, voltage gain is given by

$$\frac{V_o}{V_i} = -g_m R_D = -0.52\times 4.7 = -2.44$$

10. A single-phase, full-bridge diode rectifier fed from a 230V, 50Hz sinusoidal source supplies a series combination of finite resistance, R, and a very large inductance, L. The two most dominant frequency components in the source current are:

(A) 150 Hz, 250 Hz (B) 50 Hz, 0 Hz

(C) 50 Hz, 100 Hz (D) 50 Hz, 150 Hz

Key: (D)

Sol: Given, $1-\phi$ full bridge diode rectifier

Source: 230V, 50Hz

We have to find 2 most dominant frequencies in the source current.

We know Fourier series of source current in $1-\phi$ full bridge rectifier is given by

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$$I_s = \sum_{n=1,3,5...}^{\infty} \frac{4I_o}{n\pi} \sin n\omega t$$

$\therefore$ For n = 1 and 3, we have 1 × 50Hz and 3 × 50 Hz as the most dominant frequencies.

11. $ax^3 + bx^2 + cx + d$ is a polynomial on real x over real coefficients a, b, c, d wherein $a \neq 0$. Which of the following statements is true?

(A) a, b, c, d can be chosen to ensure that all roots are complex.

(B) C alone cannot ensure that all roots are real

(C) No choice of coefficients can make all roots identical

(D) d can be chosen to ensure that x = 0 is a root for any given set a, b, c.

Key: (A, D)

Sol: Given, A polynomial : $ax^3 + bx^2 + cx + d$

Where x, a, b, c, d are all real and $a \neq 0$

Let's check the option one by one

Option A: If d = 0, then the polynomial equation becomes

$ax^3 + bx^2 + cx = 0$

or, $x\left(ax^2 + bx + c\right) = 0$

or, $x = 0$ or $ax^2 + bx + c = 0$

$\Downarrow$

root $\Rightarrow$ d can be choosen to ensure $x = 0$ is a root of given polynomial.

Hence, option (A) is correct.

Option B: A third degree polynomial equation with all root equal is given by

$\left(x + \alpha\right)^3 = 0$

Thus, by selecting suitable values of a, b, c and d we can have all roots identical.

Hence, option (B) is incorrect.

Option (C): Complex roots always occurs in pairs,

So, the given polynomial will have maximum of 2 complex roots and 1 real root.

Hence, option (C) is incorrect.

Option (D): Nature or roots depends on other coefficients also apart from coefficient 'c'.

Hence, option (D) is correct.

Hence, the correct options are (A) and (D).

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12. Which of the following statements is true about the two sided Laplace transform?

(A) It exists for every signal that may or may not have a Fourier transform.

(B) It has no poles for any bounded signal that is non-zero only inside a finite time interval.

(C) If a signal can be expressed as weighted sum of shifted one sided exponentials, then its Laplace Transform will have no poles.

(D) The number of finite poles finite zeroes must be equal

Key: (B)

Sol: In this case we need to pick the correct statement for 2-sided Laplace transform.

As per option A: It exists for every signal that may or may not have Fourier transform.

Ex: Sgn(t), D.C: they have F.T but not two-sided L.T.

So, option A is wrong.

As per option (B): It has no poles for any bounded signal that is nonzero in a finite time interval.

This is true as we know for finite amplitude finite width signal ROC is entire s plane and ROC never includes any pole. It implies for such signals there is no poles.

Hence the correct answer is option (B).

13. A sequence detector is designed to detect precisely 3 digits input, with overlapping sequences detectable. For the sequence (1, 0, 1) and input data (1, 1, 0, 1, 0, 0, 1, 1, 0, 1, 0, 1, 1, 0), what is the output of this detector?

(A) 1, 1, 0, 0, 0, 0, 1, 1, 0, 1, 0, 0

(B) 0, 1, 0, 0, 0, 0, 0, 1, 0, 1, 1, 0

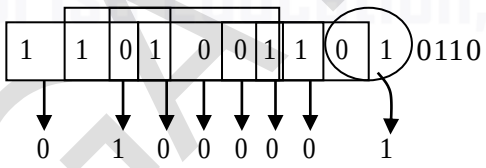
(C) 0, 1, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0

(D) 0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0

Key: (C)

Sol: Given.

Input data & sequence (101)



$\Rightarrow$ 010000010100 is the correct answer

Hence the correct option is (C).

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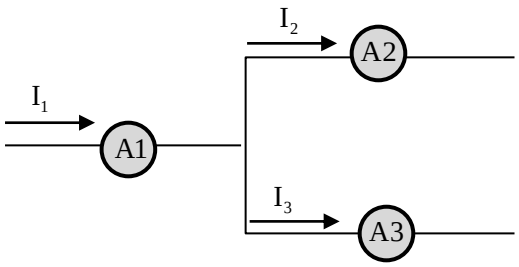
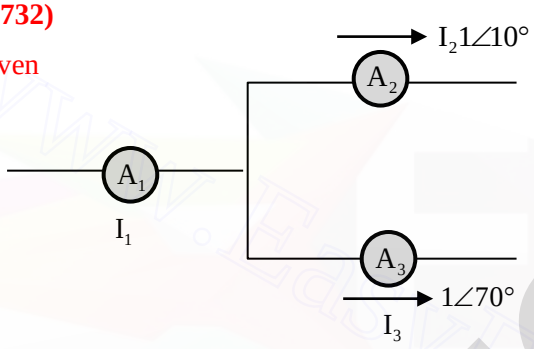
14. Currents through ammeters A2 and A3 in the figure are $1\angle 10°$ and $1\angle 70°$, respectively. The reading of the ammeter A1(rounded off to 3 decimal places) is _____A.



Key: (1.732)

Sol: Given



We need to calculate magnitude of I_1

Using KCL,

$$I_1 = I_2 + I_3 = 1\angle 10 + 1\angle 70°$$
$$= \cos 10 + j\sin 10 + \cos 70 + j\sin 70$$
$$|I| = 1.732A$$

Hence the magnitude of $I_1 = 1.732A$

15. A three-phase cylindrical rotor synchronous generator has synchronous reactance X_s and a negligible armature resistance. The magnitude of per phase terminal voltage is V_A and the magnitude of per phase induced emf is E_A. Consider the following two statements, P and Q.

P. For any three-phase balanced leading load connected across the terminals of this synchronous generator, V_A is always more than E_A

Q. For any three-phase balanced lagging load connected across the terminals of this synchronous generator, V_A is always less than E_A

(A) P is false Q is false

(B) P is true and Q is false

(C) P is true and Q is true

(D) P is false and Q is true

Key: (D)

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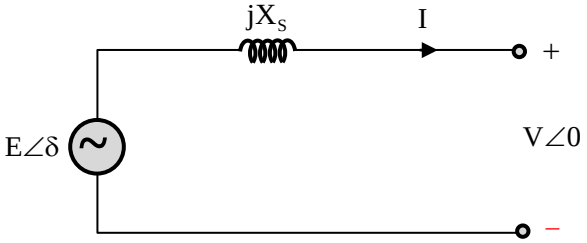
Sol: Given, $3-\phi$ cylindrical synchronous generator with synchronous reactance $=X_S$

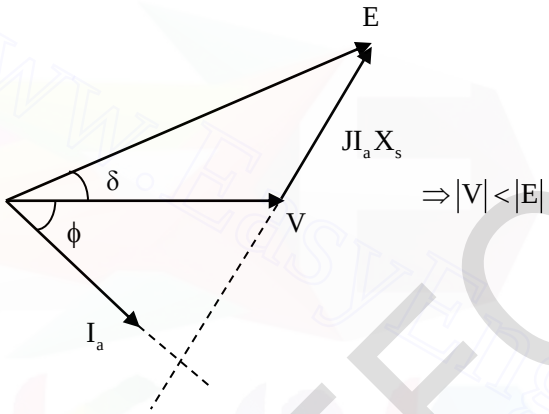
Armature resistance $=R_a=0$

We know, simplified figure of a synchronous generator looks like as shown below



Case 1: Load nature is lagging

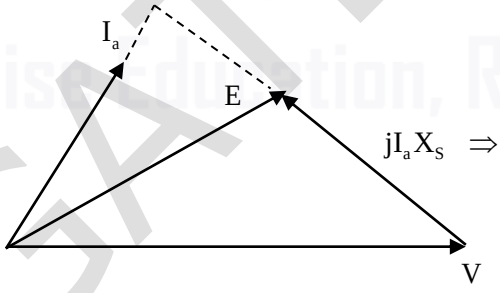
The corresponding phasor diagram is



$\Rightarrow |V| < |E|$

Case 2: Load nature is leading

The corresponding phasor diagram is



$\Rightarrow |E| < |V|$

Hence, the correct option is (D).

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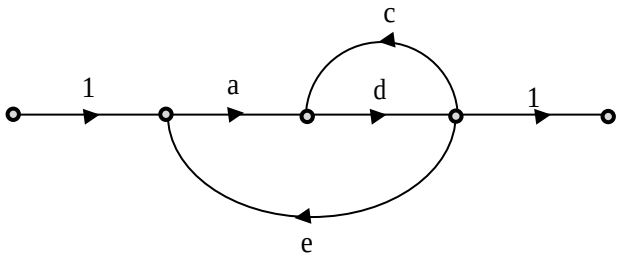
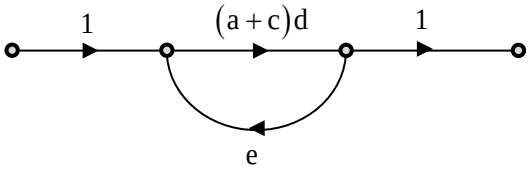
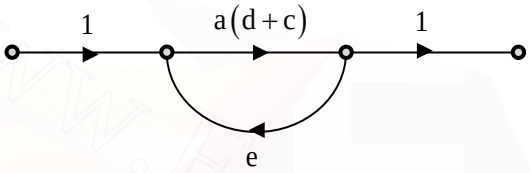
16. Which of the options is an equivalent representation of the signal flow graph shown here?



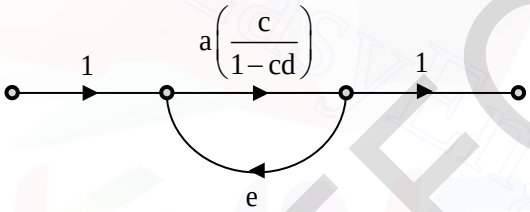
(A)



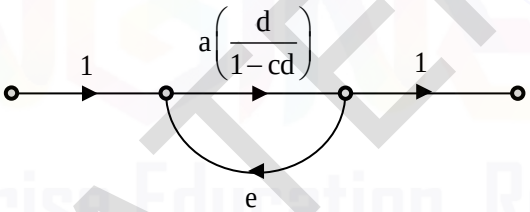
(B)



(C)



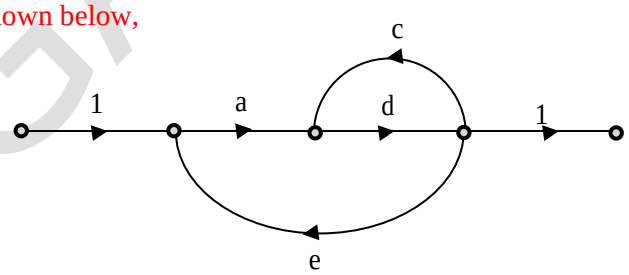
(D)



Key: (D)

Sol: Given,

SFG as shown below,



We have to choose the equivalent signal flow graph (SFG) from the options given.

Forward paths,

$P_1 = ad$

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Individual loops,

$L_1 : ade$

$L_2 : cd$

$\therefore$ From mason gain formula,

$$TF = \frac{\Sigma P_k \Delta_k}{\Delta} = \frac{P_1 \Delta_1}{\Delta} = \frac{ad \times 1}{1-(ade+cd)} = \frac{ad}{1-d(ae+c)}$$

Now, by options, we find option (D) has the same transfer function as above i.e.

$$TF' = \frac{\frac{ad}{1-cd}}{1-\frac{acd}{1-cd}} = \frac{ad}{1-cd-aed} = \frac{ad}{1-d(ae+c)}$$

Hence, the correct option is (D).

17. A single-phase, 4 kVA, 200 V/100 V, 50 Hz transformer with laminated CRGO steel core has rated no - load loss of 450 W. When the high-voltage winding is excited with 160V, 40 Hz sinusoidal ac supply, the no-load losses are found to be 320W. When the high-voltage winding of the same transformer is supplied from a 100V, 25 Hz sinusoidal ac source, the no-load losses will be _____ W (rounded off two 2 decimal places).

Key: (162.5)

Sol: Given, with 200V, 50Hz at primary,

Iron loss, $P_i = 450W$

With 160V, 40Hz, $P_i = 320W$

With 100V, 25Hz, $P_i = ?$

We know, when $\frac{V}{f} = \text{constant}$, then iron loss is given by

$P_i = af + bf^2$

$450 = 50a + 50^2 b \quad \ldots(i)$

$320 = 40a + 40^2 b \quad \ldots(ii)$

Solving (i) and (ii)

a = 4, b = 0.1

Then, at 100V, 25 Hz,

$$P_i = 4(25) + 0.1(25)^2$$
$$= 100 + 62.5$$
$$= 162.5W$$

Hence, the correct answer is 162.5W.

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18. Consider a linear time-invariant system whose input r(t) and output y(t) are related by the following differential equation:

$$\frac{d^2y(t)}{dt^2}+4y(t)=6r(t)$$

The poles of this system are at

(A) +2, –2 (B) +4, –4 (C) +2j, –2j (D) +4j, –4j

Key: (C)

Sol: Given, $\frac{d^2y(t)}{dt^2}+4y(t)=6r(t)$

We have to find poles of the system

Taking Laplace of given equation, we have

$s^2Y(s)+4Y(s)=6R(s)$

or, $Y(s)\left[s^2+4\right]=6R(s)$

or, $\frac{Y(s)}{R(s)}=\frac{6}{(s^2+4)}$

$\therefore$ Poles : $s^2+4=0\Rightarrow s=\pm j2$

19. Which of the following is true for all possible non-zero choices of integers m, n; $m\neq n$, or all possible non-zero choices of real numbers p, q; $p\neq q$, as applicable?

(A) $\frac{1}{\pi}\int_0^{\pi}\sin m\theta\sin n\theta d\theta=0$ (B) $\frac{1}{2\pi}\int_{-\pi}^{\pi}\sin p\theta\cos q\theta d\theta=0$

(C) $\frac{1}{2\pi}\int_{-\pi/2}^{\pi/2}\sin p\theta\sin q\theta d\theta=0$ (D) $\lim_{\alpha\to\infty}\frac{1}{2\alpha}\int_{-\alpha}^{\alpha}\sin p\theta\sin q\theta d\theta=0$

Key: (D)

Sol: $\lim_{\alpha\to\infty}\frac{1}{2\alpha}\int_{-\alpha}^{\alpha}\sin p\theta\,.\sin q\theta\,d\theta$

$=\lim_{\alpha\to\infty}\frac{1}{2\alpha}2\int_0^{\alpha}\sin p\theta\sin q\theta\,d\theta$

$=\lim_{\alpha\to\infty}\frac{1}{2\alpha}\int_0^{\alpha}\left[\cos(p-q)\theta-\cos(p+q)\theta\right]d\theta$

$=\lim_{\alpha\to\infty}\frac{1}{2\alpha}\left[\frac{\sin(p-q)\theta}{(p-q)}-\frac{\sin(p+q)\theta}{(p+q)}\right]_0^{\alpha}$

$=\lim_{\alpha\to\infty}\frac{1}{2\alpha}\left[\frac{\sin(p-q)\alpha}{(p-q)}-\frac{\sin(p+q)\alpha}{(p+q)}\right]$

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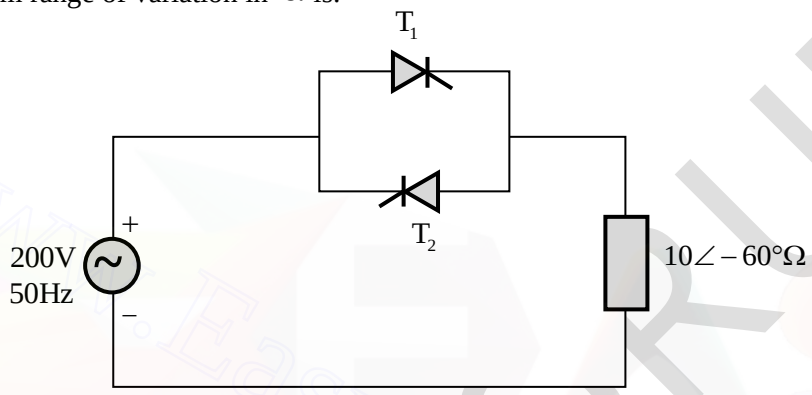
$$= 0 \left[\begin{array}{l} \text{if } \alpha \to \infty \text{ then } \sin(p-q)\alpha \,\&\, \sin(p+q)\alpha \in [-1,1] \\ \& \dfrac{\sin(p-q)\alpha}{2\alpha(p-q)} \,\&\, \dfrac{\sin(p+q)\alpha}{2\alpha(p+q)} \to 0 \end{array} \right]$$

20. Thyristor T_1 is triggered at an angle $\alpha(\text{in degree})$, and T_2 at angle $180° + \alpha$, in each cycle of the sinusoidal input voltage. Assume both thyristors to be ideal. To control the load power over range 0 to 2kW, the minimum range of variation in α is:



(A) 0° to 60° (B) 60° to 180° (C) 0° to 120° (D) 60° to 120°

Key: (C)

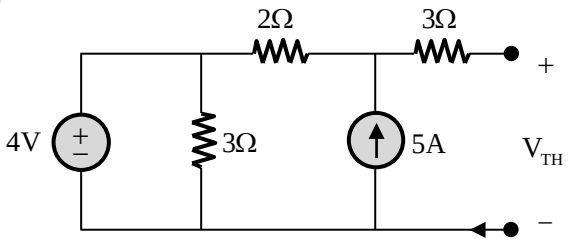
Sol: $\text{Load} = 10\angle -60\Omega$ leading load

Since given load is leading in nature. Hence to control the load power over range 0 to 2kW. The minimum range of variation in α is $0°$ to $120°$

Hence the correct option is (C)

Note: For lagging load answer would be $60°$ to $180°$

21. The Thevenin equivalent voltage, V_{TH}, in V (rounded off two 2 decimal places) of the network shown below, is _____.



Key: (14)

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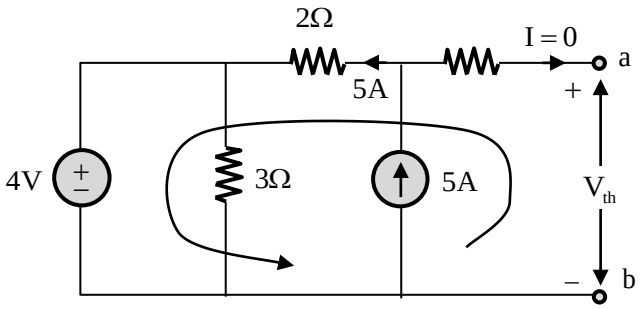
Sol: Given,



We have to find V_{th} across ab

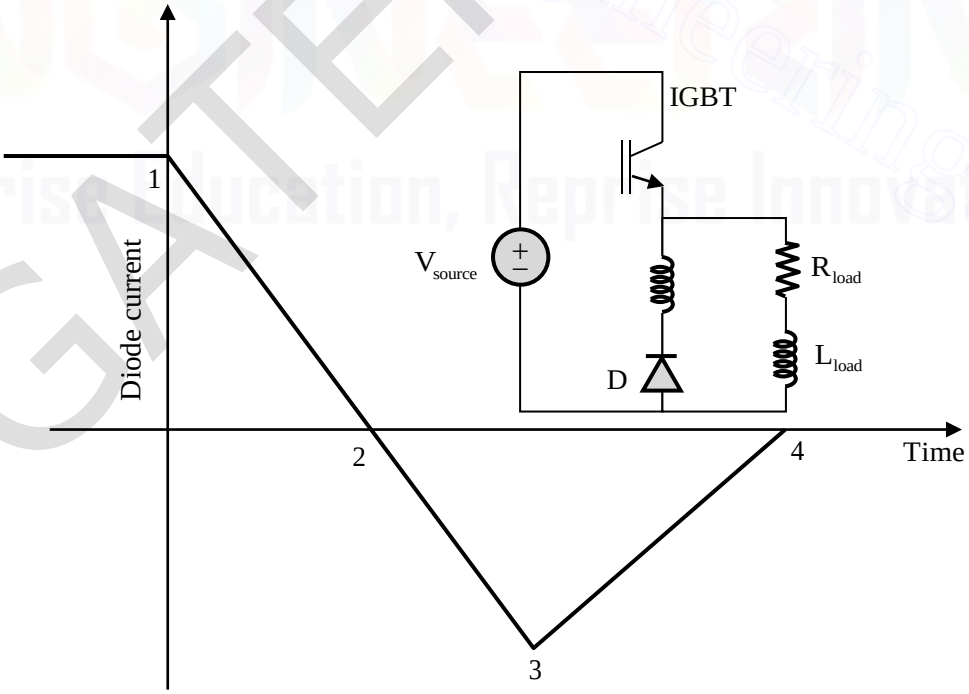
Applying KVL in above circuit as shown,

$V_{th} - 2\times5 - 4 = 0$

$V_{th} = 10 + 4 = 14V$

Hence, the correct answer is 14V

22. A double pulse measurement for an inductivity loaded circuit controlled by the IGBT switch is carried out to evaluate the reverse recovery characteristics of the diode, D, represented approximately as a piecewise linear plot of current vs time at diode turn-off. L_{par} is a parasitic inductance due to the wiring of the circuit, and is in series with the diode. The point on the plot (indicate your choice by entering 1, 2, 3 or 4) at which the IGBT experiences the highest current stress is _____.



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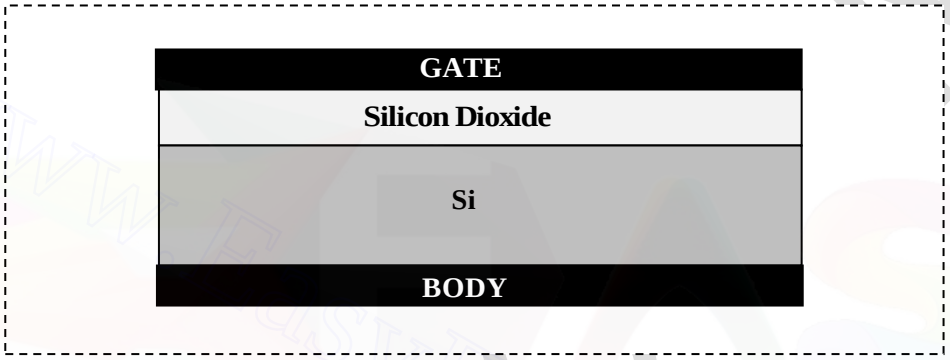
Key: **(3)**

Sol: Since reverse recovery current will follow through IGBT and I_R = maximum at point 3.

Hence at point 2 stress will be maximum.

23. The cross-section of a metal-oxide-semiconductor structure is shown schematically. Starting from an uncharged condition, a bias +3V is applied to the gate contact with respect to the body contact. The charge inside the silicon dioxide layer is then measured to be +Q. The total charge contained within the dashed box shown, upon application of bias, expressed as a multiple of Q (absolute value in Coulombs, rounded off to the nearest integer) is _____.



Key: **(0)**

Sol: The voltage applied at the gate with the substrate as reference, gives rise to an electric field in the insulator which is sustained by the space charge on the two sides of the insulating layer. The space charge region in the semiconductor can be understood from the following consideration. From the condition of charge neutrality or charge balance of the MOS structure, the space charge density in the semiconductor at the Si-SiO_2 interface equals that on the gate induced by the applied voltage. The above condition is mathematically expressed by:

$$Q_g + Q_{sc} = 0$$

$$\text{or } Q_g = -Q_{sc}$$

Where Q_g is the total gate charge, and Q_{sc} is total space charge in the substrate at the interface. Thus, for a positive voltage applied to the gate, the conducting gate electrode is charged positive, and the net space charge on the semiconductor adjoining the insulating layer is negative.

24. Consider a signal $x[n]=\left(\frac{1}{2}\right)^n 1[n]$, where $1[n]=0$ if $n<0$, and $1[n]=1$ if $n\geq 0$. The z-transform of $x[n-k], k>0$ is $\frac{z^{-k}}{1-\frac{1}{2}z^{-1}}$ with region of convergence being

(A) $|z|<1/2$ (B) $|z|<2$ (C) $|z|>2$ (D) $|z|>1/2$

Key: **(D)**

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Sol: Given, $x(n)=\left(\frac{1}{2}\right)^n U(n)$; Where $U(n)=0$ if $n<0$

$=1$ if $n\geq 0$

We have to find ROC of z-transform of $x(n-k), k>0$

We know,

$a^n u(n) \xrightarrow{ZT} \frac{1}{1-az^{-1}}; ROC: |z|>|a|$

If $x(n) \xrightarrow{ZT} X(z); ROC: R$

Then, $x(n-n_0) \xrightarrow{ZT} Z^{-n_0}X(z); ROC: R$

i.e., ROC remain same with time shifting

Taking Z-transform of x(n),

$$X(z)=\frac{1}{1-\frac{1}{2}z^{-1}}; |z|>\frac{1}{2}$$

And, $z[x(n-k)]=\frac{z^{-k}}{1-\frac{1}{2}z^{-1}}; |z|>\frac{1}{2}$

{Since ROC remains same with time shifting}

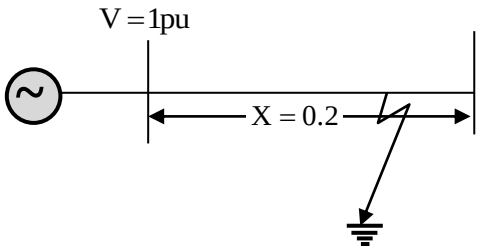
Hence, the correct option is (D).

25. A lossless transmission line with 0.2 pu reactance per phase uniformly distributed along the length of the line, connecting a generator bus to a load bus, is protected up to 80% of its length by a distance relay placed at the generator bus. The generator terminal voltage is 1 pu. There is no generation at the load bus. The threshold pu current for operation of the distance relay for a solid three phase to ground fault on the transmission line is closest to:

(A) 5.00 (B) 6.25 (C) 1.00 (D) 3.61

Key: (B)

Sol: Given,



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Impedance upto fault location $= 0.8X = 0.8 \times 0.2 = 0.16\,\text{pu}$

Impedance by impedance relay $= \dfrac{V}{I_f} = \dfrac{1}{I_f}$

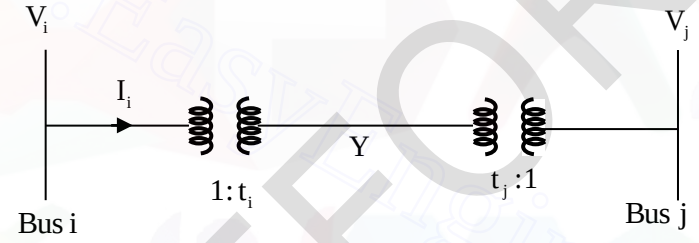
For relay to operate, limiting case is

$\dfrac{1}{I_f} = 0.16 \Rightarrow I_f = 6.25$

Hence, option (B) is correct.

Q. No. 26 to 55 Carry Two Marks Each

26. Two buses, i and j, are connected with a transmission line of admittance Y, at the two ends of which there are ideal transformers with turns ratio as shown. Bus admittance matrix for the system is:

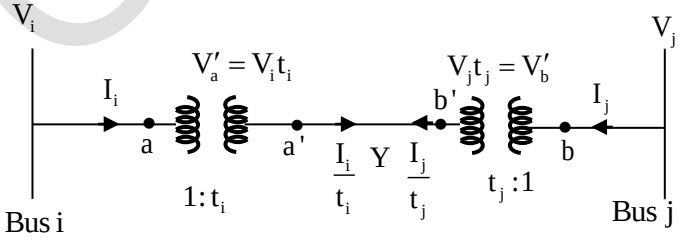


(A) $\begin{bmatrix} t_i^2 Y & -t_i t_j Y \\ -t_i t_j Y & t_j^2 Y \end{bmatrix}$ (B) $\begin{bmatrix} -t_i t_j & -t_j^2 Y \\ -t_i^2 Y & t_i t_j Y \end{bmatrix}$

(C) $\begin{bmatrix} t_j t_j Y & -t_j^{\,2} Y \\ -t_i^2 Y & t_i t_j Y \end{bmatrix}$ (D) $\begin{bmatrix} t_i t_j Y & -(t_i - t_j)^2 Y \\ -(t_i - t_j)^2 Y & t_i t_j Y \end{bmatrix}$

Key: (A)

Sol: Given,



We have to find admittance matrix of above two bus system

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Current through Y are

$$\frac{I_i}{t_i} = \left(V_a' - V_b'\right)Y = \left(V_i t_i - V_j t_j\right)Y$$

$$\text{and } \frac{I_j}{t_j} = \left(V_b' - V_a'\right) = \left(V_j t_j - V_i t_i\right)Y$$

Above equation can be written as

$$I_i = t_i^2 Y V_i + \left(-t_i t_j Y\right)V_j$$

$$I_j = \left(-t_i t_j Y\right)V_i + \left(t_i^2 Y\right)V_j$$

Comparing above equation's with standard equations of Y parameters, we have

$$\text{Admittance matrix } [Y] = \begin{bmatrix} t_i^2 Y & -t_i t_j Y \\ -t_i t_j & t_i^2 Y \end{bmatrix}$$

27. A 250 V dc shunt motor has an armature resistance of 0.2Ω and a field resistance of 100Ω. When the motor is operated no-load at rated voltage, it draws an armature current of 5A and runs at 1200 rpm. When a load is coupled to the motor, it draws total line current of 50A at rated voltage, with a 5% reduction in the air-gap flux due to armature reaction. Voltage drop across the brushes can be taken as 1V per brush under all operating conditions. The speed of the motor, in rpm, under this loaded condition, is closet to:

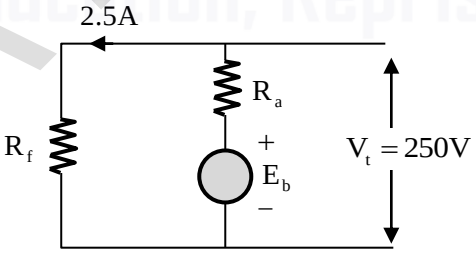
(A) 1220 (B)900 (C) 1200 (D) 1000

Key: (A)

Sol: Given,

$V_t = 250V, R_a = 0.2\Omega, R_f = 100\Omega$ and $I_{a,NL} = 5A, N_{NL} = 1200\text{rpm}, I_{LFL} = 50A$ and $\phi_{2FL} = 0.95\phi_{1NL}$.

Voltage drop across the brushes are 1V/brush. We need to compute the speed of the motor, in rpm under loaded condition



$$\left(I_{a_2FL}\right) = \left(I_{LFL}\right) - I_f = 50 - 2.5 = 47.5A$$

Since $E_b \propto N\phi$

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$$\Rightarrow \frac{E_{b_1NL}}{E_{b_2FL}} = \frac{N_{NL}}{N_{FL}} \times \frac{\phi_{1NL}}{\phi_{2FL}}$$

$$\Rightarrow \frac{250 - 0.2 \times 5 - 2}{250 - 47.5 \times 0.2 - 2} = \frac{1200 \times \phi_{1NL}}{N_{FL} \times 0.95 \times \phi_{1NL}}$$

$$\Rightarrow \frac{247}{238.5} = \frac{1200}{N_{FL} \times 0.95}$$

$$N_{FL} = 1219.68 \text{ rpm} \approx 1220 \text{ rpm}$$

Hence, the speed of motor in rpm under loaded condition, is 1220 rpm.

28. A stable real linear time-invariant with single pole at p, has transfer function $H(s) = \frac{s^2 + 100}{s - p}$ with a dc gain of 5. The smallest positive frequency, in rad/s, at unity gain is closest to:

(A) 122.87 (B) 78.13 (C) 11.08 (D) 8.84

Key: (D)

Sol: Given,

$$H(s) = \frac{s^2 + 100}{s - p} \text{ and dc gain} = 5$$

We need to compute smallest positive frequency in rad/s at unity gain.

For dc gain s = 0

$$\frac{100}{-p} = 5 \Rightarrow p \Rightarrow -20$$

$$H(s) = \frac{s^2 + 100}{s + 20}$$

$$\Rightarrow H(j\omega) = \frac{(j\omega)^2 + 100}{j\omega + 20} \Rightarrow |H(j\omega)| = \frac{100 - \omega^2}{\sqrt{\omega^2 + 400}} = 1$$

$$\Rightarrow \omega^4 - 201\omega^2 + 9600 = 0$$

$$\Rightarrow \omega^2 = 122.860 \text{ and } 78.138$$

$$\omega = 11.08 \text{ and } 8.84 \text{ rad/s}$$

$$\downarrow$$

smallest frequency

Hence the smallest positive frequency in rad/sec at unity gain is 8.84 rad/s.

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29. The number of purely real elements in a lower triangular representation of the given 3 × 3 matrix, obtained through the given decomposition is _____.

$$\begin{bmatrix}2 & 3 & 3\\ 3 & 2 & 1\\ 3 & 1 & 7\end{bmatrix}=\begin{bmatrix}a_{11} & 0 & 0\\ a_{12} & a_{22} & 0\\ a_{13} & a_{23} & a_{33}\end{bmatrix}\begin{bmatrix}a_{11} & 0 & 0\\ a_{12} & a_{22} & 0\\ a_{13} & a_{23} & a_{33}\end{bmatrix}$$

(A) 6 (B) 5 (C) 8 (D) 9

Key: (D)

Sol: Given that,

$$\begin{bmatrix}2 & 3 & 3\\ 3 & 2 & 1\\ 3 & 1 & 7\end{bmatrix}=\underset{\text{LTM}}{\begin{bmatrix}a_{11} & 0 & 0\\ a_{12} & a_{22} & 0\\ a_{13} & a_{23} & a_{33}\end{bmatrix}}\underset{\text{UTM}}{\begin{bmatrix}a_{11} & a_{12} & a_{13}\\ 0 & a_{22} & a_{23}\\ 0 & 0 & a_{33}\end{bmatrix}}$$

$$=\begin{bmatrix}(a_{11})^2 & a_{11}a_{12} & a_{11}a_{13}\\ a_{12}a_{11} & (a_{12})^2+(a_{22})^2 & a_{12}a_{13}+a_{22}a_{23}\\ a_{13}a_{11} & a_{13}a_{12}+a_{23}a_{22} & (a_{13})^2+(a_{23})^2+(a_{33})^2\end{bmatrix}$$

$\therefore a_{11}^2=2\Rightarrow a_{11}=\pm\sqrt{2}$

$a_{11}a_{12}=3\Rightarrow a_{11}^2a_{12}^2=9$

$\Rightarrow a_{12}^2=9/2\Rightarrow a_{12}=\pm3/\sqrt{2}$

$a_{11}a_{13}=3$

$a_{11}^2a_{13}^2=9\Rightarrow 2\,a_{13}^2=9\Rightarrow a_{13}^2=9/2\Rightarrow a_{13}=\pm3/\sqrt{2}$

$(a_{12})^2+(a_{22})^2=2\Rightarrow\frac{9}{2}+(a_{22})^2=2\Rightarrow(a_{22})^2=2-9/2$

$=-5/2\Rightarrow a_{22}=\pm\sqrt{-5/2}\rightarrow$ imaginary

If a_{22} is imaginary them a_{23} and a_{33} also becomes imaginary numbers.

$\therefore$ The number of purely real elements in a lower triangular representation is 9

$\left(a_{11}=\pm\sqrt{2};a_{12}=\pm3/\sqrt{2};a_{13}=\pm3/\sqrt{2},0,0,0\right)$

30. The static electric field inside a dielectric medium with relative permittivity, $\varepsilon_r=2.25$, expressed in cylindrical coordinate system is given by the following expression.

$$E=a_r2r+a_\varphi\left(\frac{3}{r}\right)+a_z6$$

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Where a_r, a_φ, a_z are unit vectors along r, φ and z directions respectively. If the above expression represents a valid electrostatic field inside the medium, then the volume charge density associated with this field in terms of free space permittivity, ε_0, in SI units is given by:

(A) $3\varepsilon_0$ (B) $4\varepsilon_0$ (C) $5\varepsilon_0$ (D) $9\varepsilon_0$

Key: (D)

Sol: Given

$$E_{static} = a_r 2r + a_\phi \left(\frac{3}{r}\right) + a_z 6 \text{ and } \varepsilon_r = 2.25$$

If the above expression represents a valid electrostatic field inside the medium, then the volume charge density associated with this field need to calculate.

$$\rho_v = \nabla.\vec{D} = \nabla\varepsilon_r\ \varepsilon_0\vec{E}$$

$$\rho_v = \varepsilon_r\ \varepsilon_0\left(\nabla.\vec{E}\right)$$

$$\nabla\vec{E} = \frac{1}{r}\left(\frac{\partial}{\partial r}(r.2r) + \frac{\partial}{\partial\phi}\left(\frac{3}{r}\right) + \frac{\partial}{\partial z}(6)\right)$$

$$= \frac{1}{r}4r + 0 + 0$$

$$= 4$$

$$\rho_v = \varepsilon_r\varepsilon_o 4 \Rightarrow \left(\because \nabla.\vec{E} = 4\right)$$

$$\rho_v = 2.25\varepsilon_o 4 = 9\varepsilon_o$$

$$\rho_v = 9\varepsilon_o\ C/m^3$$

Hence, the volume charge density is $9\varepsilon_o$.

31. An 8085 microprocessor accesses two memory locations (2001H) and (2002H), that contain 8-bit numbers 98H and B1H, respectively. The following program is executed:

LXI H, 2001 H

MVI A, 21H

INX H

ADD M

INX H

MOV M, A

HLT

At the end of this program, the memory location 2003H contains the number in decimal (base 10) form_____.

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Key: (210)

Sol: In this case we need to obtain the decimal equivalent of number stored in memory location 2003H at the end of execution of 8085 based given program.

LXI H, 2001H: Load HL register with 2001:

H	L
20	01

MVI A, 21H: Move 21 to accumulator: 21 A

INX H: Increment the content of HL pair by 1

H	L
20	02

ADD M: Add the content of accumulator with the number whose memory location address is in HL pair. S store result in accumulator.

Since HL pair content is 2002, address 2002 contains B1

So $(B1)_{16} + (21)_{16} \rightarrow A$ D2 A

So A = D2

INX H: Increment content of HL pair by 1

H	L
20	03

MOV M, A: Move the content of accumulator to the location whose address is stored in HL pair,

Since HL pair contains 2003, now content of accumulator $(D2)_{16}$ will be moved to location 2003.

HLT: Halt

So, at the end memory location 2003 contain

$(D2)_{16} = (210)_{10}$

Hence the correct answer is 210.

32. The causal realization of a system transfer function H(s) having poles at (2, –1), (–2, 1) and zeroes at (2, 1), (–2, –1) will be

(A) Unstable, complex, all pass

(B) unstable, real, highpass

(C) stable, complex, lowpass

(D) stable, real, allpass

Key: (A)

Sol: Given, a Causal system having transfer function H(s) with poles at (2, –1), (–2, 1) and zeros at (2, 1), (–2, –1).

We have to comment upon the following

Stability

Complex or real

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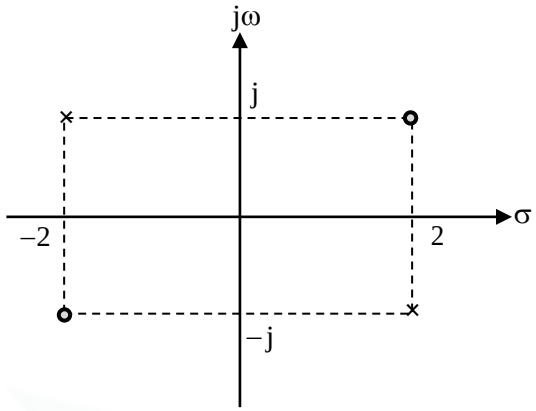
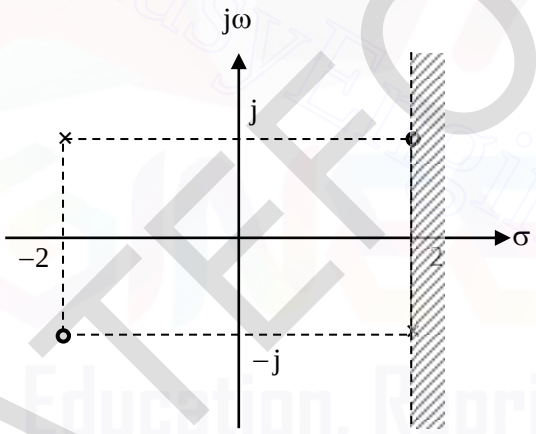
Low pass or high pass or all pass.

The pole zero plot is as shown below



Transfer function $H(s)=\frac{\left[s-(2+j)\left[s-(-2-j)\right]\right]}{\left[s-(2-j)\right]\left[s-(2+j)\right]}=\frac{(s-2-j)(s+2+j)}{(s+2+j)(s-2-j)}$

Stability: Since the system is causal, its ROC is as shown below



As the ROC does not include positive $j\omega$ axis, it is an unstable system.

Nature of filter

Putting $s=j\omega$ in H(s),

$$H(j\omega)=\frac{(j\omega-2-j)(j\omega+2+j)}{(j\omega+2+j)(j\omega+2-j)}$$

$$\text{or, } |H(j\omega)|=\frac{\sqrt{4+(1-\omega)^2}\sqrt{4+(1+\omega)^2}}{\sqrt{4+(1+\omega)^2}\sqrt{4+(1-\omega)^2}}=1$$

i.e., $|H(j\omega)|=1$ for all ω

$\Rightarrow$ It is an all pass filter

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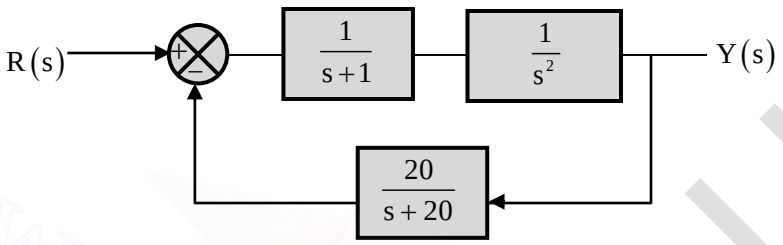
Real or complex

A system is real of its poles and zeros occur in conjugate pairs but here it is not so, therefore given system is complex in nature.

Hence, the correct option is (B).

33. Which of the following options is correct for the system shown below?



(A) 4th order and stable

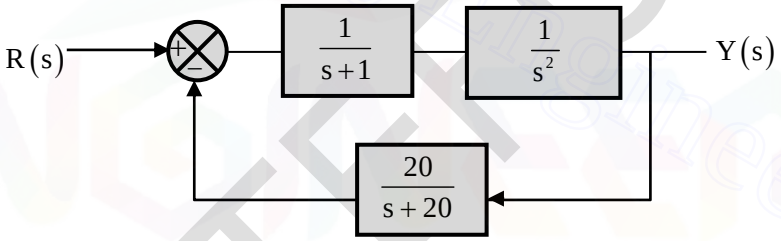
(B) 4th order and unstable

(C) 3rd order and unstable

(D) 3rd order and stable

Key: (B)

Sol: Given,



We have to comment upon order and stability of the given system

The transfer function of overall system is

$$\frac{Y(s)}{R(s)} = \frac{\frac{1}{s^2(s+1)}}{1+\frac{1}{s^2(s+1)}\cdot\frac{20}{(s+20)}}$$

$$= \frac{s+20}{s^2(s+1)(s+20)+20}$$

$$= \frac{s+20}{\underset{\text{order}=4}{\underset{\downarrow}{s^4}} + 21s^3 + 20s^2 + 20}$$

The system is unstable because a term of s is missing in the characteristics equation of above transfer function.

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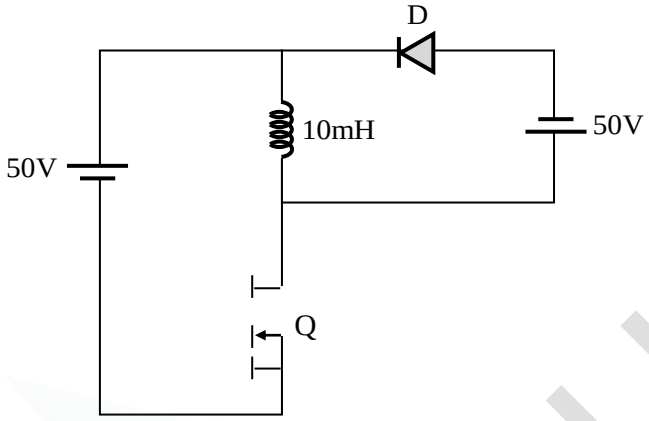
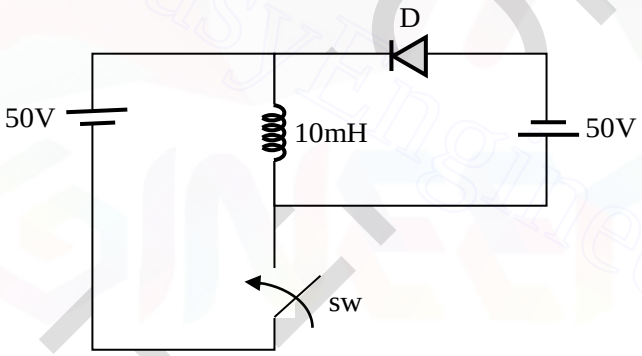
34. In the dc-dc converter circuit shown, switch Q is switched at a frequency of 10 kHz with a duty ratio of 0.6. All components of the circuit are ideal, and the initial current in the inductor is zero. Energy stored in the inductor in mJ (rounded off to 2 decimal places) at the end of 10 complete switching cycles is _____.



Key: **(5)**

Sol: Given, f = 10 kHz, D = 0.6

We need to calculate energy stored in the inductor in mJ at the end of 10 complete switching cycle.



When switch is closed or ON,

$$\frac{L\Delta I_L}{\Delta T} = V_S = 50$$

$$\Delta I_L = \frac{50\times 0.6}{10\times 10^3 \times 10\times 10^{-3}} = 0.3A$$

During OFF

$$\Delta I_L = \frac{50\times 0.4}{10\times 10m} = 0.2A$$

$$\therefore I_{L\,min} = 0.3 - 0.2A = 0.1A$$

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Similarly,

Number of cycles	I_L (end of cycle)
1	0.1A
2	0.2A
10	01A

$\therefore$ Current stored in inductor at the end of 10^{th} cycle = 1A

Energy stored $= \frac{1}{2}LI^2 = \frac{1}{2} \times 10m \times 1^2 = 5mJ$

Hence the correct answer is 5mJ.

35. The vector function expressed by

$$F = a_x(5y - k_1 z) + a_y(3z + k_2 x) + a_z(k_3 y - 4x)$$

represents a conservative field, where a_x, a_y, a_z are unit vectors along x, y and z directions, respectively. The values of constants k_1, k_2, k_3 are given by:

(A) $k_1 = 3, k_2 = 8, k_3 = 5$

(B) $k_1 = 4, k_2 = 5, k_3 = 3$

(C) $k_1 = 3, k_2 = 3, k_3 = 7$

(D) $k_1 = 0, k_2 = 0, k_3 = 0$

Key: (B)

Sol: Given,

$$\vec{F} = a_x\{5y - k_1 z\} + a_y(3z + k_2 x) + a_z(k_3 y - 4x)$$

F represents a conservative field. We need to calculate $k_1.k_2$ and k_3

$\because \vec{F}$ is a conservative field

i.e., $\nabla \times \vec{F} = 0$

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$$\nabla \times \vec{F} = \begin{vmatrix} a_x & a_y & a_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ (5y - k_1 z) & (3z + k_2 x) & (k_3 y - 4x) \end{vmatrix} = 0$$

$$\Rightarrow a_x(k_3 - 3) + (-a_y)(-4 + k_1) + a_2(k_2 - 5) = 0$$

$k_3 - 3 = 0, \quad k_3 = 3$

$k_2 - 5 = 0, \quad k_2 = 5$

$k_1 - 4 = 0, \quad k_1 = 4$

Hence $k_1 = 4, k_2 = 5$ and $k_3 = 3$ for conservative field $(\vec{F})$.

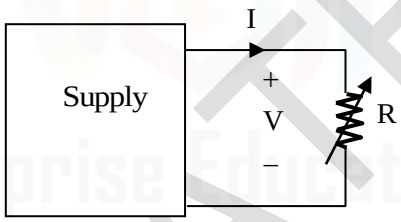
36. A benchtop dc power supply acts as an ideal 4 A current source as long as its terminal voltage is below 10V. Beyond this point, it begins to behave as an ideal 10V voltage source for all load current going down to 0A. When connected to an ideal rheostat, find the load resistance value at which maximum power is transferred, and the corresponding load voltage and current.

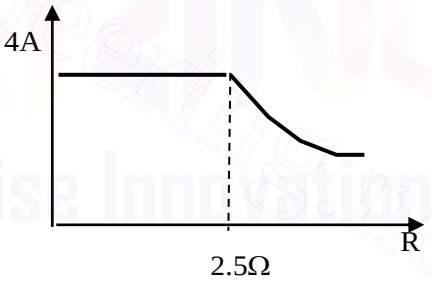
(A) 2.5Ω, 4A, 10V (B) Open, 4A, 0V

(C) Short, ∞A, 10V (D) 2.5Ω, 4A, 5V

Key: (A)

Sol: Given,



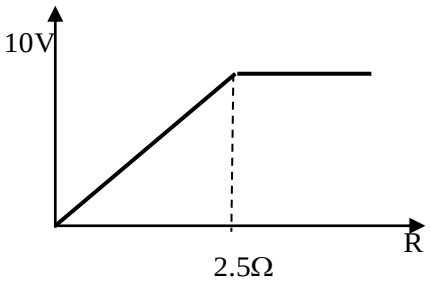


If supply acts as 4A current source

$V = 4R, \; P = 4^2 R$

$\therefore V_{max} = 10V. \; R_{min} = 2.5\Omega \left\{ \because \frac{10}{4} = 2.5\Omega \right\}$

$P_{max} = 16 \times 2.5 = 40W$



Now, if supply acts as 10V source,

$I = \frac{10}{R}, \; P = \frac{10^2}{R}$

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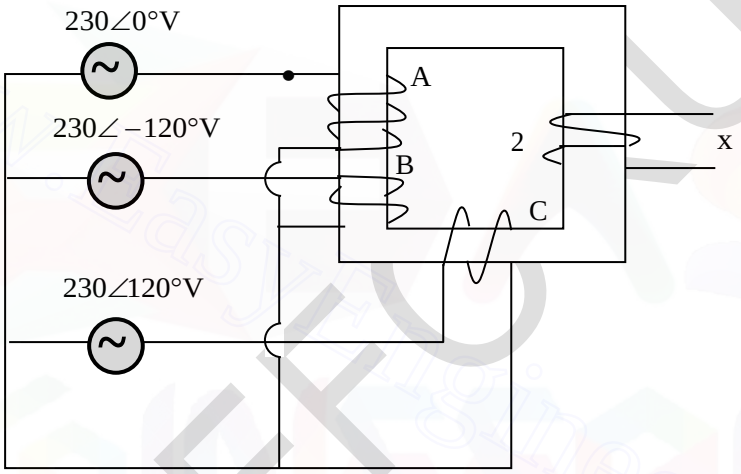
This occurs for R>2.5 , $P_{max} = \frac{10^2}{2.5} = 40W$

$\therefore R = 2.5\Omega,\ V = 10V, I = 4A$

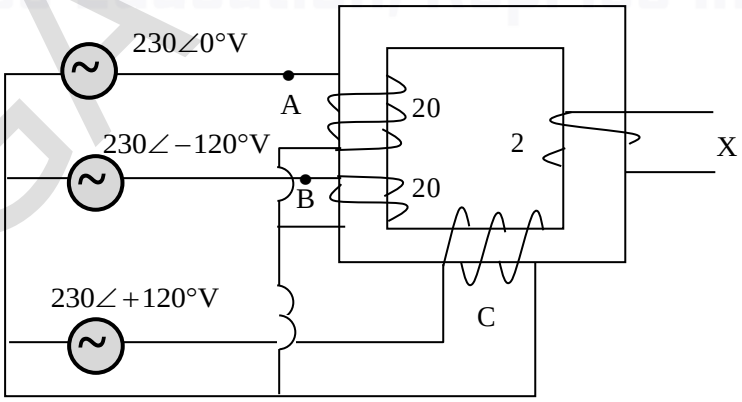
Hence correct option is (A)

37. Windings 'A', 'B' and 'C' have 20 turns each and are wound on the same iron core as shown, along with winding 'X' which has 2 turns. The figures shows the sense (clockwise/anti-clockwise) of each of the windings only and does not reflect the exact number of turns. If windings 'A', 'B' and 'C' are supplied with balanced 3-phase voltages at 50 Hz and there is no core saturation, the no-load RMS voltage (in V, rounded off two 2 decimal places) across winding 'X' is _____.



Key: (46)

Sol: Given



We need to calculate V_X

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$$V_X = \frac{-2}{20} \times 230\angle 0° + \frac{2}{20} 230\angle -120 + \frac{2}{20} 230\angle 120°$$
$$= -23\angle 0 + 23\angle -120° + 23\angle 120°$$
$$= 23\angle 180° + 23\angle -120° + 23\angle 120°$$
$$V_X = 46\angle 180^o \text{ V}$$

Hence, no load RMS voltage (in V) across winding X is 46V.

38. A single-phase, full-bridge, fully controlled thyristor rectifier feeds a load comprising a 10Ω resistance in series with a very large inductance. The rectifier is fed from an ideal 230V, 50Hz sinusoidal source through cables which have negligible internal resistance and a total inductance of 2.28mH. If the thyristors are triggered at an angle $\alpha = 45°$, the commutation overlap angle in degree (rounded off to 2 decimal places) is _____.

Key: **(4.8)**

Sol: Given,

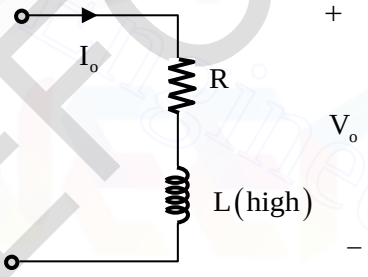
$R_L = 10\Omega$ and L_L = Very high, $V_S = 230\text{V}, 50\text{Hz}$.

$L_s = 2.28\text{mH}$ and $\alpha = 45°$,

We need to calculate the commutation overlap angle in degree for single phase full controlled rectifier.

$$I_o = \frac{V_m}{2\omega L_s}\{\cos\alpha - \cos(\alpha + \mu)\}$$

$$V_o = \frac{2V_m}{\pi}\cos\alpha - \frac{2\omega L_s I_o}{\pi}$$



$$V_o = I_o R$$
$$(I_o = \text{constant for L(high)})$$

$$\Rightarrow I_o \times 10 = \frac{2 \times 230\sqrt{2}}{\pi}\cos 45° - \frac{2 \times 100\pi \times 2.28\text{mH} \times I_o}{\pi}$$

$$\Rightarrow I_o(10.456) = 146.42\text{V}$$

$$I_o = 14.0036\text{A}$$

Now, we have to use I_o expression to get μ (over lap angle)

$$\Rightarrow 14.0036 = \frac{230\sqrt{2}}{2 \times 100\pi \times 2.28 \times 10^{-3}}\{\cos 45° - \cos(45° + \mu)\}$$

$$\Rightarrow \cos(45° + \mu) = 0.645$$

$$45° + \mu = 49.80$$

$$\mu = 4.8019 \text{ degree}$$

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39. Consider a negative unity feedback system with the forward path transfer function $\frac{s^2+s+1}{s^3+2s^2+2s+K}$, where K is a positive real number. The value of K for which the system will have some of its poles on the imaginary axis is _____.

(A) 9 (B) 6 (C) 7 (D) 8

Key: (D)

Sol: Given

$$G(s)=\frac{s^2+s+1}{s^3+2s^2+2s+K}$$

$$H(s)=1.$$

We need to find K value for which the system will have same of its poles on $j\omega$ axis.

Characteristics equation,

$$\Rightarrow s^3+2s^2+2s+K+s^2+s+1=0$$

$$\Rightarrow s^3+3s^2+3s+(1+K)=0$$

$$IP=EP$$

$$\Rightarrow 9=1+K$$

$$K_{max}=8$$

Hence the correct answer is 8.

40. A cylindrical rotor synchronous generator has steady state synchronous reactance of 0.7 pu and subtransient reactance of 0.2 pu. It is operating at (1+ j0) pu terminal voltage with an internal emf of (1 + j0.7) pu. Following a three-phase solid short circuit fault at the terminal of the generator, the magnitude of the sub transient internal emf (rounded off to 2 decimal places) is _____pu.

Key: (1.02)

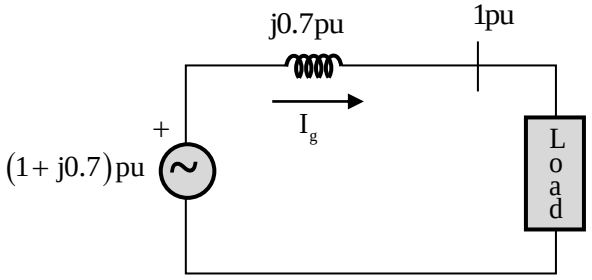
Sol: Given,

$X_d=0.7pu$ and $X_d''=0.2pu$ (sub transient reactance)

$V_t=(1+j0)pu$ and emf $(internal)=(1+j0.7)pu$

We need to find magnitude of the sub transient internal emf.

At steady state



$$I_{steady\ state}=\frac{1+j0.7-1}{j0.7}=1\angle 0°$$

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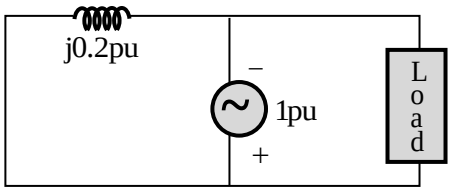
During fault,



$$\Delta I_g = \frac{1}{j0.2} = 5\angle -90^\circ \text{ pu}$$

Total current = steady state current + transient current

$= I_g + \Delta I_g$

$= I\angle 0 + 5\angle -90^\circ = (1 - j5)$

During fault $E_g'' = I_g$ during fault $\times$ j0.2

$= (1 - j5)\, j0.2$

$= 1 + 0.2\,j \cong 1.02\text{pu}$

Hence, the magnitude of the sub-transient emf is 1.02 pu.

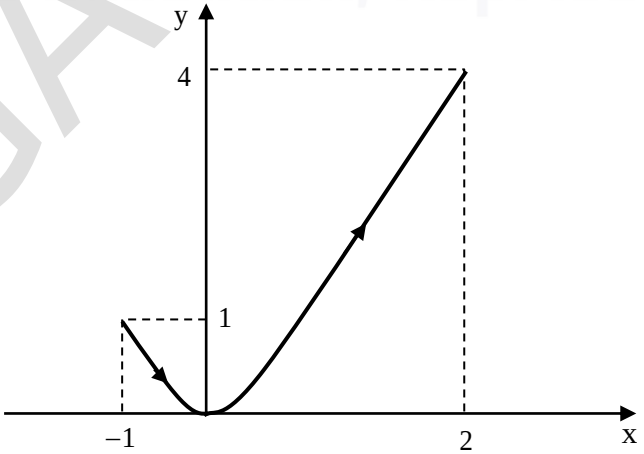
41. Let a_x and a_y be unit vectors along x and y directions, respectively. A vector function is given by

$$F = a_x y - a_y x$$

The line integral of the above function

$$\int_C F.dt$$

Along the curve C, which follows the parabola $y = x^2$ as shown is _____(rounded off to 2 decimal places).



Key: (-3)

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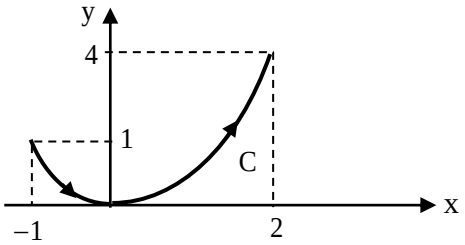
Sol: Given,

$f = a_x y - a_y x$ and $\int_C f.dl \rightarrow$need to calculate.

C follows the parabola $y = x^2$



The line integral

$= \int_C \vec{F}.dl = \int \left(ya_x - a_y x\right)\left(dxa_x + dya_y + dza_z\right)$

$= \int \left(ydx - xdy\right) = \int x^2 dx - x\left(2x\right)dx$

$= -\int x^2 dx \qquad \{Q\ y = x^2, dy = 2xdx\}$

$= -\int_1^2 x^2 dx = \left|\frac{x^3}{3}\right|_1^2 = \left\{\left(\frac{2^3}{3}\right) + \frac{1}{3}\right\} = -3$

Hence the correct answer is –3.

42. A cylindrical rotor synchronous generator with constant real power output and constant terminal voltage is supplying 100A current to a 0.9 lagging power factor load. An ideal reactor is now connected in parallel with the load, as a result of which the total lagging reactive power requirement of the load is twice the previous value while the real power remains unchanged. The armature current is now _____A (rounded off two 2 decimal places).

Key: (125.3)

Sol: Given,

P = constant and V = constant $I_1 = 100A$ and 0.9 pf lag.

If Q become twice then we need compute I_2.

$\tan\phi = \tan\left\{\cos^{-1} 0.9\right\} \rightarrow$ when case – I , $Q' = Q$

$\tan\phi = 2\tan\left[\cos^{-1} 0.9\right] \rightarrow$ when case – II, $Q' = 2Q$

$= 0.9686$

pf in second condition,

$pf_2 = 0.7182$

Since P = constant

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$I_1 \cos\phi_1 = I_2 \cos\phi_2 = 0$

$100 \times 0.9 = 0.7182\, I_2$

$I_2 = \dfrac{100 \times 0.9}{0.7182} = 125.29 \approx 125.3\text{A}$

$I_2 = 125.3\text{A}$

Here, new armature current is now 125.3A

43. Which of the following options is true for a linear time-invariant discrete time system that obeys the difference equation:

$$y[n] - ay[n-1] = b_0 x[n] - b_1 x[n-1]$$

(A) The system is necessarily causal

(B) The system impulse response is non-zero at infinitely many instants.

(C) When $x[n] = 0, n < 0$, the function $y[n]; n > 0$ is solely determined by the function x[n].

(D) y[n] is unaffected by the values of x[n – k]; k > 2

Key: (B)

Sol: It is given that

$$y(n) - ay(n-1) = b_0 x(n) - b_1 x(n-1)$$

We need to pick the correct statement.

By taking the z-transform both side

$$Y(z) - az^{-1}Y(z) = b_0 X(z) - b_1 z^{-1} X(z)$$

$$\Rightarrow \frac{Y(z)}{X(z)} = \frac{b_0 - b_1 z^{-1}}{1 - az^{-1}}$$

$$\Rightarrow H(z) = \frac{b_0}{1 - az^{-1}} - \frac{b_1 z^{-1}}{1 - az^{-1}}$$

Since $H(\tau)$ has one pole at a, it can have 2 possible inverse z-transform.

If $|Z| > |a| \Rightarrow h_1(n) = b_0 a^n u(n) - b_1 a^{n-1} u(n-1) \Rightarrow$ causal $h(n) = 0, n < 0$

If $|z| < |a| \Rightarrow h_2(n) = -b_0 a^n u(-n-1) + b_1 a^{n-1} u(-n)$

non causal $h(n) \neq 0; n < 0$

So, system is not necessarily causal, so option A is wrong.

From the expression of $h_1(n)$ and $h_2(n)$ we can say the impulse response is non zero of infinitely many instants.Hence the correct answer is option (B).

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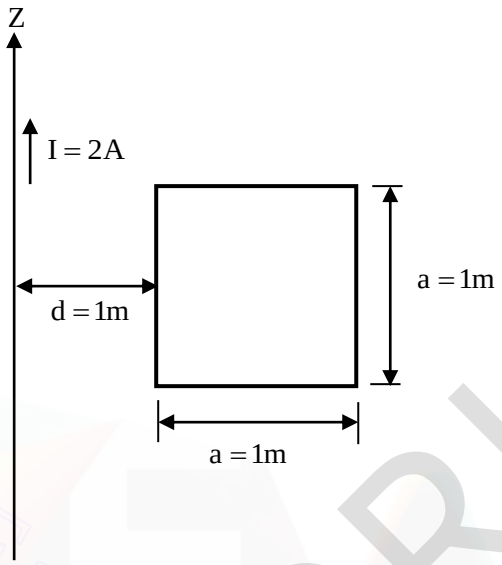
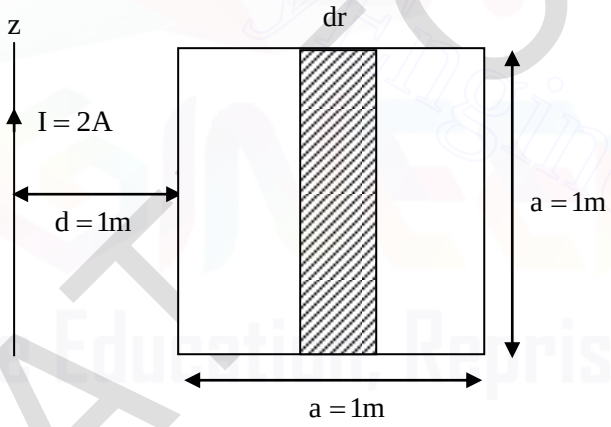
44. A conducting square loop of side length 1 m is placed at distance of 1m from a long straight wire carrying a current I = 2 A as shown below. The mutual inductance, in nH (rounded off to 2 decimal places), between the conducting loop and the long wire is _____.



Key: (138.6)

Sol: Given,



We need to compute the mutual inductance between the conduction loop and the long wire

Magnetic field density $B = \frac{\mu_o I}{2\pi r}$ (Q at the distance r from the wire).

$$d\phi_m = B.dA = B.adr = \frac{\mu_o I}{2\pi r} a\, dr$$

$$\phi_m = \int_d^{a+d} \frac{\mu_o I}{2\pi r} a\, dr = \frac{a\mu_o I}{2\pi} \int_d^{a+d} \frac{1}{r} dr$$

$$\phi_m = \frac{\mu_o I_a}{2\pi} \left[\ln x \right]_d^{a+d} = \frac{\mu_o Ia}{2\pi} \left[\ln(a+d) - \ln d \right] = \frac{\mu_o Ia}{2\pi} \left\{ \ln\left(\frac{a+d}{d} \right) \right\}$$

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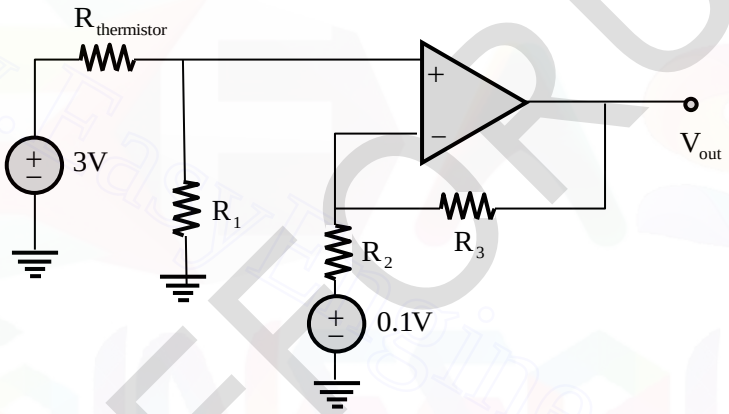
The mutual inductance $= M = \frac{\phi_m}{I} = \frac{\mu.a}{2\pi} \ln\left(\frac{a+d}{d}\right)$

$= \frac{4\pi \times 10^{-7} \times 1}{2\pi} \ln 2 = 138.6 \text{ nH}$

Hence, the mutual inductance between the conduction loop and the long wire is 138.6nH.

45. The temperature of the coolant oil bath for a transformer is monitored using the circuit shown, It contains a thermistor with a temperature-dependent resistance, $R_{thermistor} = 2(1+\alpha T)k\Omega$, where T is the temperature in °C. The temperature coefficient, α, is $-(4 \pm 0.25)\%/°C$. Circuit parameters: $R_1 = 1k\Omega, R_2 = 1.3k\Omega, R_3 = 2.6k\Omega$. The error in the output signal (in V, rounded off two 2 decimal places) at 150°C is _____.



Key: (0.083)

Sol: According to circuit diagram

$$V_{out} = 3 \times \frac{R_1}{R_1 + R_{th}} \left\{1 + \frac{R_3}{R_2}\right\} - 0.1\frac{R_3}{R_1} = 2 \times \frac{1}{1 + R_{th}} \left\{1 + \frac{2.6}{1.3}\right\} - 0.1 \times \frac{2.6}{1.3}$$

$$= \frac{3 \times 3}{1 + R_{Th}} - 0.2$$

$$= \frac{9}{1 + R_{Th}} - 0.2$$

$$R_{Th} \text{ at } 150^o = 2\left\{1 - \frac{4}{100} \times 150\right\} = -10k\Omega$$

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$V_o = \frac{9}{1-10} - 0.2 = -1.2V$

If $\alpha = -(4 + 0.25)$

$R_{Th} = 2\left\{1 - \frac{4.25}{100} \times 150\right\} = -10.75k\Omega$

V_o when $R_{th} = -10.75k\Omega$ is $\frac{9}{1-10.75} - 0.2 = -1.123V$

Error = 0.077V

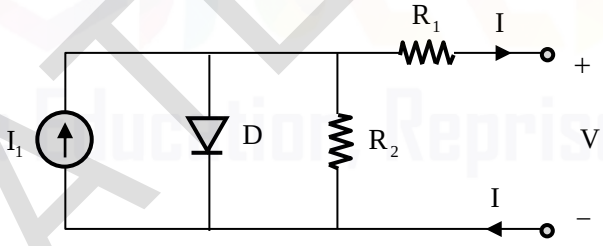
if $\alpha = -(4 - 0.25)$

$R_{th} = 2\left(1 - \frac{3.75}{100} \times 150\right) = -9.25k\Omega$

$V_o = -1.29$ errror $= 0.09V$

Average errror $= \frac{0.09 + 0.077}{2} = 0.083V$

46. Consider the diode circuit shown below, The diode, D, obeys the current-voltage characteristic $I_D = I_S\left(\exp\left(\frac{V_D}{nV_T}\right) - 1\right)$, where n > 1, $V_T > 0$, V_D is the voltage across the diode and I_D is the current through it. The circuit is biased so that voltage, V > 0 and current, I < 0. If you had to design this circuit to transfer maximum power from the current source (I_1) to a resistive load (not shown) at the output, what values of R_1 and R_2 would you choose?



(A) Small R_1 and large R_2

(B) Small R_1 and small R_2

(C) Large R_1 and large R_2

(D) Large R_1 and small R_2

Key: (A)

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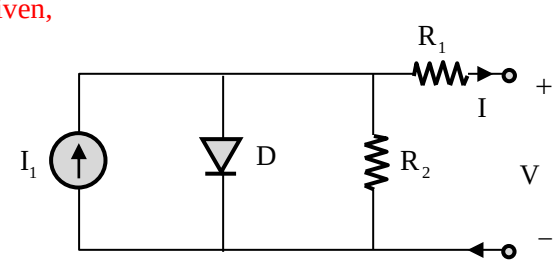
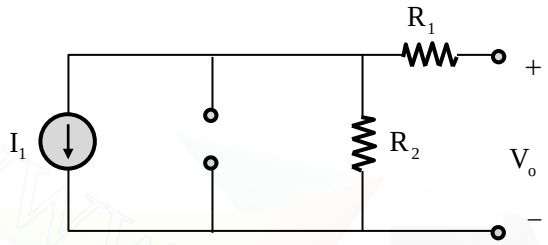
Sol: Given,



$$I_D = I_S\left\{\exp\left(\frac{V_D}{nV_P}\right)-1\right\}$$

$$I_1 < 0$$

$\therefore$ For maximum power V should be maximum and I_1 should pass through load.



Since I_1 is reverse $(\because I_1 < 0A)$

$\therefore$ R_2 should be large and R_1 should be minimum.

If R_2 is high $\rightarrow$ Whole I_1 will try to pass through load, and $R_1 \rightarrow$ less, reduces the drop.

Hence the correct answer is small R_1 and large R_2.

47. For real numbers, x and y, with $y = 3x^2 + 3x + 1$, the maximum and minimum value of y for $x \in [-2, 0]$ are respectively, _____.

(A) 1 and 1/4 (B) 7 and 1 (D) 7 and 1/4 (D) –2 and –1/2

Key: (C)

Sol: Given $y = 3x^2 + 3x + 1$, we need to calculate maximum and minimum value of y for $x \in [-2, 0]$,

$f(x) = y = 3x^2 + 3x + 1$

Since, $x \in [-2,\ 0]$

↓

Closed interval

Hence absolute maximum and minimum value need to consider

$\Rightarrow f'(x) = 6x + 3 = 0$

$x = -0.5$

Now we have to check minima and maxima point.

$f'(x) = 6 > 0$

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$\therefore$ Point x = –0.5 is point of minima

$f(x)\big|_{\text{at } x=-2} = 3(-2)^2 - 6 + 1 = 7$

$f(x)\big|_{\text{at } x=-0.5} = 3(-0.5)^2 + 3(-0.5) + 1 = \frac{1}{4}$

$f(x)\big|_{\text{at } x=0} = 1$

$\therefore$ Maximum value of y = 7 and minimum value of $y = \frac{1}{4}$.

Hence maximum and minimum value of y are 7 and $\frac{1}{4}$ respectively.

48. A resistor and a capacitor are connected in series to a 10V dc supply through a switch. The switch is closed at t = 0, and the capacitor voltage is found to cross 0V at $t = 0.4\tau$. Where τ is the circuit time constant. The absolute value of percentage change required in the initial capacitor voltage if the zero crossing has to happen at $t = 0.2\tau$ is _____ (rounded off to 2 decimal places).

Key: (54.9)

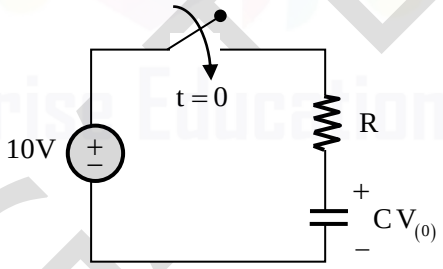
Sol: Given,

$V_{supply} = 10V$ and RC network

Case I: The capacitor voltage is found to cross 0V at $t = 0.4\tau$.

Case II: The capacitor voltage is found to cross 0V at $t = 0.2\tau$

We need to find the absolute value of change required in the initial capacitor voltage considering boththe cases.



$V_{(0)} = V_{C_1} \rightarrow \text{Case1}$

$V_{(0)} = V_{C_2} \rightarrow \text{Case 2}$

$V_{(\infty)} = 10V$ (for both cases)

The capacitor voltage $V_C(t)$ is given by

$V_C(t) = V_C(\infty) + \left[V_C(0) - V_C(\infty)\right]e^{-t/\tau}$

From Case-I

$0 = 10 + \left(V_{C_1} - 10\right)e^{-0.4}$

$V_{C_1} = -4.91V$

From case-II:

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$0 = 10 + \left(V_{C_2} - 10\right)e^{-0.2} \Rightarrow V_{C_2} = -2.214V$

Thus, the absolute % change in initial capacitor

$$\text{Voltage} = \left|\frac{V_{C_2} - V_{C_1}}{V_{C_1}}\right| \times 100 = \left|\frac{-2.214 + 4.91}{4.91}\right| \times 100 = 54.9\%$$

49. Let a_r, a_ϕ and a_z be unit vectors along r, ϕ and z directions, respectively in the cylindrical coordinate system. For the electric flux density given by $D = \left(a_r 15 + a_\phi 2r - a_z 3rz\right)$ Coulomb/m^2, the total electric flux, in Coulomb, emanating from the volume enclosed by a solid cylinder of radius 3m and height 5m oriented along the z-axis with its base at the origin is:

(A) 108π (B) 54π (C) 180π (D) 90π

Key: (C)

Sol: Given,

$D = \left(a_r 15 + a_\phi 2r - a_z 3rz\right)$, We need to calculate total electric flux for r = 3m and z = 0 to 5m

$$\psi_{total} = \oint D.ds = \int (\nabla.D)\,dV$$

$$\nabla.D = \frac{1}{\rho}\left[\frac{\partial}{\partial\rho}(\rho.15) + \frac{\partial}{\partial\phi}(2\rho) + \frac{\partial}{\partial z}(-3\rho z)\rho\right]$$

$$= \frac{1}{\rho}\left[15 - 3\rho^2\right]$$

$$= \frac{15}{\rho} - 3\rho$$

$$\psi_{total} = \iiint\left(\frac{15}{\rho} - 3\rho\right)\rho\,d\rho\,d\phi\,dz \{dV = \rho\,d\rho\,d\phi\,dz\}$$

$$= \int_{\rho=0}^{3}\int_{\phi=0}^{2\pi}\int_{z=0}^{5}\frac{15}{\rho}\rho\,d\rho\,d\phi\,dz - \int_0^3\int_0^{2\pi}\int_0^5 3\rho^2\,d\rho\,d\phi\,dz$$

$$= 15(3)(2\pi)5 - (27)(2\pi)5$$

$$= 10\pi[45 - 27] = 180\pi$$

Hence, total electric flux enclosed by given cylinder is 180π.

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50. Suppose for input x(t), a linear time-invariant system with impulse response h(t) produces output y(t), so that x(t) * h(t) = y(t). Further, if $|x(t)|*|h(t)|=z(t)$, which of the following statements is true?

(A) For all $t\in(-\infty,\infty), z(t)\geq y(t)$

(B) For some but not all $t\in(-\infty,\infty), z(t)\geq y(t)$

(C) For all $t\in(-\infty,\infty), z(t)\leq y(t)$

(D) For some but not all $t\in(-\infty,\infty), z(t)\leq y(t)$

Key: (A)

Sol: It is given that

$$x(t)*h(t)=y(t)$$
$$|x(t)|*|h(t)|=z(t)$$

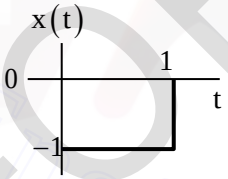
We need to comment about $z(t)$ and $y(t)$ relation.

Such kind of question can be answered based on case study of examples.

Case-I:

Let $x(t)=-[u(t)-u(t-1)]$

$h(t)=\delta(t)$

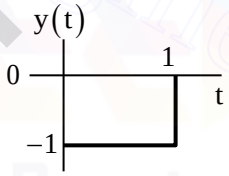


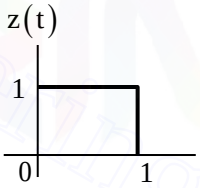
(i) Then $y(t)=x(t)*\delta(t)=x(t)$

(ii) Then $z(t)=|x(t)|*|h(t)|$

$=|-[u(t)-u(t-1)]|*|\delta(t)|$

$=[u(t)-u(t-1)]*\delta(t)$





By comparing y(t) and z(t) we can say $z(t)\geq y(t)$ for all $t\in(-\infty,\infty)$

Case-II:

Let $x(t)=-e^{-at}u(t)$

$h(t)=u(t)$

(i) Then $y(t)=x(t)*h(t)$

$=-e^{-at}u(t)*u(t) \qquad (a>0)$

$=-\left[\frac{1}{a}\left(1-e^{-at}\right)\right]u(t)$

(ii) Then $z(t)=|x(t)|*|h(t)|=|-e^{-at}u(t)|*|u(t)|=e^{-at}u(t)*u(t)=\frac{1}{a}\left(1-e^{-at}\right)u(t)$

Again $z(t)\geq y(t)$ for all t.

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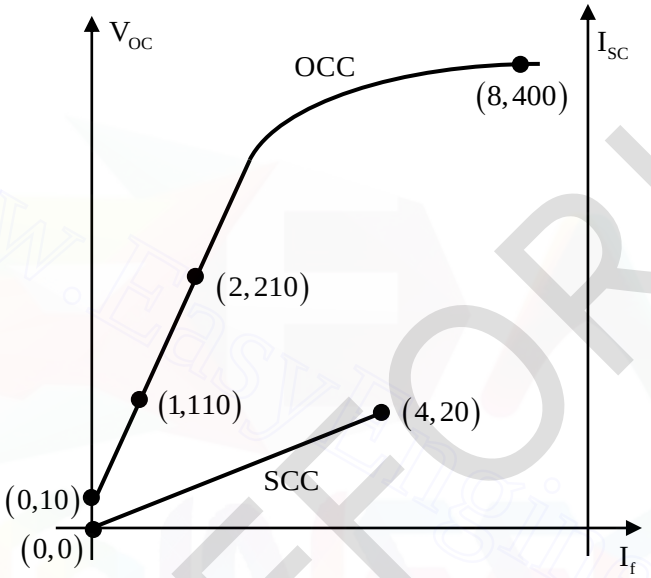
From above 2 example we can say option B, C, D are not true.

Hence the correct answer is option (A).

51. The figure below shows the per-phase open circuit characteristics (measured in V) and short circuit characteristics (measured in A) of a 14 kVA, 400V, 50Hz, 4-pole, 3-phase, delta, connected alternator, driven at 1500 rpm. The field current, I_f is measured in A. Readings taken are marked as respective (x, y) coordinates in the figure. Ratio of the unsaturated and saturated synchronous impedances $\left(Z_{s(unsat)}/Z_{s(sat)}\right)$ of the alternator is closet to:



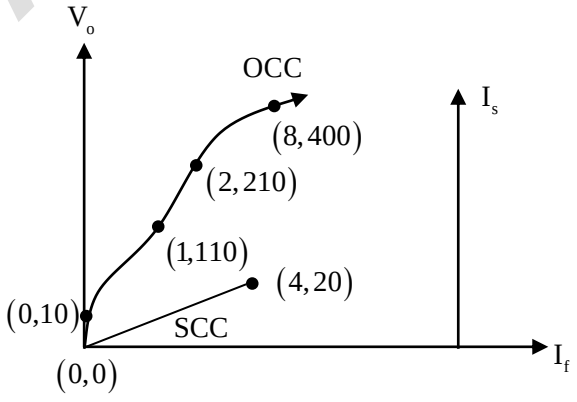
(A) 1.000 (B) 2.025 (C) 2.100 (D) 2.000

Key: (C)

Sol: Given,

Machine rating, 14kVA, 400V, 50Hz and 15000 rpm,

P = 4 and 3-phase delta connected



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We need to calculate $\left(Z_{s(unsat)}\right)/Z_{s(sat)}$

$$Z_{s(sat)} = \left.\frac{V_{oc}}{I_{sc}}\right|_{I_f = \text{at saturation of OCC}} = \frac{(400)}{(20\times 2)} = 10\Omega \quad \begin{Bmatrix} Q\ I_{sc} = 20A \text{ at } 2A \text{ field current} \\ I_{sc} = 40A \text{ at } 4A \text{ field current} \end{Bmatrix}$$

$$Z_{s(unsat)} = \left.\frac{V_{oc}}{I_{sc}}\right|_{I_f = \{I_f \text{ value of } I_{sc} \text{ rated}\}} = \frac{210}{10} = 21\Omega$$

$$\therefore \frac{Z_{s(unsat)}}{Z_{s(sat)}} = \frac{21}{10} = 2.1$$

Hence, the ratio of unsaturated and saturated synchronous impedance of alternator is closest to 2.1.

52. Consider a permanent magnet dc (PMDC) motor which is initially at rest. At t = 0, a dc voltage of 5V is applied to the motor. Its speed monotonically increases from 0 rad/s to 6.32 rad/s in 0.5s and finally settles to 10 rad/s. Assuming that the armature inductance of the motor is negligible, the transfer function for the motor is

(A) $\frac{10}{s+0.5}$ (B) $\frac{2}{s+0.5}$ (C) $\frac{10}{0.5s+1}$ (D) $\frac{2}{0.5s+1}$

Key: (D)

Sol: $V_{supply} = 5V$ at t = 0, or 5u(t), speed increases from 0 rad/sec to 6.32 rad/s in 0.5s.

(Means time constant) = 0.5sec. Steady state value=10rad/sec, we need to calculate the transfer function for the motor.

$$V(s) = \frac{5}{s}(\text{Laplace transform of input})$$

In time constant form transfer function, final value of $w(s)$, $\frac{W(s)}{V(s)} = \frac{k}{0.5s+1}$

$$10 = \lim_{s\to 0} \frac{s\times\frac{k}{s}\times 5}{0.5s+1} \Rightarrow 5k = 10$$

$$k = 2$$

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$\therefore$ Transfer function $= G(s) = \dfrac{2}{0.5s+1}$

Hence the transfer function for the motor is $\dfrac{2}{0.5s+1}$

53. Bus 1 with voltage magnitude $V_1 = 1.1\,\text{pu}$ is sending reactive power Q_{12} towards bus 2 with voltage magnitude $V_2 = 1\,\text{pu}$ through lossless transmission line of reactance X. Keeping the voltage at bus 2 fixed at 1 pu, magnitude of voltage at bus 1 is changed, so that the reactive power Q_{12} sent from bus 1 is increased by 20%. Real power flow through the line under both the conditions is zero. The new value of the voltage magnitude V_1, in pu (rounded off to 2 decimal places), at bus 1 is _____.

Key: (1.12)

Sol: Given,

Case I: when Q_{12} flow then $V_1 = 1.1\,\text{pu}$ and $V_2 = 1\,\text{pu}$

Case II: When Q_{12} increases by 20%, then we need to compute V_1 provided $V_2 = 1\text{pu}$

It is given that real power flow through the line under both the conditions is zero

$\therefore \delta = 0$

$Q_s = \dfrac{V_1}{X}[V_1 - V_2] = \dfrac{1.1}{X} \times 0.1 \rightarrow (1)$ {From case I}

From Case-II

$1.2Q_s = \dfrac{V_1}{X}[V_1 - 1] \rightarrow (2)$ …(2) {From Case-II}

$\Rightarrow \dfrac{1}{1.2} = \dfrac{1.1 \times 0.1}{V_1[V_1 - 1]}$

$\Rightarrow V_1^2 - V_1 - 0.132 = 0 \rightarrow$ From this equation $V_1 = 1.12$ pu

Hence the new value of the voltage magnitude V_1 in pu at bus1 is 1.12 pu.

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54. A non-ideal Si-biased pn junction diode is tested by sweeping the bias applied across its terminals from –5V to +5V. The effective thermal voltage, V_T, for the diode is measured to be (29 ± 2)mV. The resolution of the voltage source in the measurement range is 1mV. The percentage uncertainty (rounded off to 2 decimal places) in the measured current at a bias voltage of 0.02V is _____.

Key: (2.934)

Sol: $\text{Since } I_D = I_s\left\{e^{\frac{V_D}{nVT}} - 1\right\} = I_s e^{\frac{V_D}{nVT}}$

$$\frac{\partial I_D}{\partial V_D} = \frac{I_s e^{\frac{V_D}{nV_T}}}{nV_T} = \frac{I_D}{nV_T}, \quad \frac{\partial I_D}{\partial V_T} = I_S e^{\frac{V_D}{nV_T}} \times \frac{-V_D}{nV_T^2}$$

Uncertainty in I,

$$\sigma_{T_B} = \left[\left(\frac{\partial I}{\partial V_D}\right)^2 \sigma_{VD}^{\ 2} + \left(\frac{\partial I}{\partial V_T}\right)^2 \sigma_{VT}^{\ 2}\right]$$

$$\sigma_{T_B} = \left[\frac{I_D^{\ 2}}{n^2 V_T^{\ 2}}\sigma_{Vo}^{\ 2} + \frac{I^2 V_o^{\ 2}}{n^2 V_T^{\ 4}}\sigma_{VT}^{\ 2}\right]$$

$$\% \text{ uncertainity} = \frac{dI_D}{I_D} \times 100 = r_{I_D} \times 100$$

$$= \left[\frac{0.001}{2^2 \times 0.029^2} + \frac{0.002^2 \times 0.02}{2^2 \times 0.029^4}\right]^{\frac{1}{2}} \times 100 = 2.937\%$$

55. A non-ideal diode is biased with a voltage of –0.03V, and a diode current of I_1 is measured. The thermal voltage is 26mV and the ideality factor for the diode is 15/13. The voltage, in V, at which the measured current increases to $1.5I_1$ is closet to

(A) –1.50 (B) –0.02 (C) –0.09 (D) –4.50

Key: (B)

Sol: In PN junction, diode

$$I\ ;\ I_o\left(e^{\frac{V_1}{\eta V_T}} - 1\right)$$

$$I_1\ ;\ I_o e^{\frac{V_1}{\eta V_T}}$$

$$I_2\ ;\ I_o e^{\frac{V_2}{\eta V_T}}$$

$$V_1 - V_2 = \eta V_T \ln\left(\frac{I_1}{I_2}\right)$$

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Given, $V_1 = -0.03, \eta = \frac{15}{3}$ & $V_T = 26\text{m}$

$$V_1 - V_2 = +30\text{m}\left(\ln\left(\frac{I_1}{1.5I_1}\right)\right)$$

$$= 30\text{m}[\ln 2 - \ln 3]$$

$$= -0.0121$$

$$V_2 = V_1 + 0.0121$$

$$= -0.03 + 0.0121$$

$$= -0.017 \approx -0.02\text{V}$$

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